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OIL CONSERVATION AND FUEL OIL SUPPLY

STUDIES OF INTERNATIONAL ECONOMIC PROBLEMS

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OIL CONSERVATION AND FUEL OIL SUPPLY

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1930

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PREFACE

FUEL resources and energy production are the basis of economic development, machine industry, transportation, commerce, international trade, and world power. In the nineteenth century, coal was the major source of energy generally available and played the leading rôle in the industrial economy. The early decades of the twentieth century have been marked by the development of other sources of energy, which have become formidable competitors of coal—fuel oil, gasoline, natural gas, and water power. From 1913 to 1927, the world's supply of coal was stationary, while the production of other, competing fuels expanded greatly.

The present competitive situation in the energy field is highly complicated. A change in the supply of any one of the several competing forms of energy has widespread effects. It necessitates a readjustment of world consumption of the various energy fuels among the different countries, among the geographical regions of consumption within these countries, and among the major uses of fuel.

The rapid development of oil consumption has given rise to serious consideration of the competitive situation in the energy field. Although the output of crude oil has increased greatly in recent years, the question of a possible future decline in the supply challenges attention. This question is especially urgent in the United States, which is the leading consumer of oil among the nations, using almost two thirds of the world's supply. The Federal Oil Conservation Board, created in 1924, has undertaken to formulate the problems involved in oil conservation and to develop cooperative effort between the petroleum industry and state and federal agencies. The conservation program for crude oil is based on three main propositions, namely, that the supply of crude oil should be considered as limited from the viewpoint of future needs, that motor fuel and lubricants are the most essential oil products, since fuel oils could be more readily replaced by coal, and that a program involving an increase in the percentage of gasoline recovered from crude oil from

the present thirty-nine per cent to sixty per cent is feasible and would result in a corresponding decline in the percentage of fuel oil produced.

Present conditions are favorable for undertaking an oil conservation program. It is evident that the difficulties in the way of successful application of conservation measures will grow with delay. The larger the volume of crude oil production and the higher the level of output to which consumption is allowed to adjust itself, the more serious will be the consequences of a future decline in supply, and the greater the difficulties of readjusting consumption on a lower level of output.

The first essential to intelligent consideration and discussion of the problem of oil conservation is comprehensive information concerning the basic facts underlying the problem. This calls for a survey of world consumption and production of the various forms of energy. In order to supply this need the Conference Board has undertaken a series of studies. The present study deals with the consumption and production of fuel oil in relation to oil conservation.

This report presents a detailed analysis of the factors that determine consumption and production of fuel oil. The various uses of fuel oil, the combination of these uses with one another, and the extent to which other sources of energy, particularly coal and natural gas, compete with the present and probable future supply of fuel oil are considered, with especial reference to the effects of a possible decline in supply under a conservation program. Such a study presupposes a preliminary survey of the position of fuel oil among the available sources of energy, and throughout the study the problems of fuel oil production and consumption are correlated with those of other sources of energy.

In the preparation of this report the National Industrial Conference Board has derived great benefit from the guidance of an Advisory Committee consisting of the following persons:

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Grateful acknowledgment is made also to the United States Bureau of Mines, the Mineral Division of the United States Bureau of Foreign and Domestic Commerce, and the American Petroleum Institute, and to others who have been consulted in the course of the study.

In the preparation of its studies the National Industrial Conference Board avails itself of the experience and judgment of the business executives who compose its membership and of recognized authorities in special fields, in addition to the scientific knowledge and equipment of its Research Staff. The publications of the Conference Board thus finally represent the result of scientific investigation and broad business experience, and the conclusions expressed therein are those of the Conference Board as a body.

The present volume has been prepared by Alfred G. White and assistants, of the Conference Board's Research Staff, under the supervision of the Board's Staff Economic Council.

MAGNUS W. ALEXANDER,
President

New York
August, 1930

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PART I

MODERN SOURCES OF WORLD ENERGY

OIL CONSERVATION AND FUEL OIL SUPPLY

SUMMARY

PART I is a brief survey of the chief sources of modern energy and their competition with each other. Such a survey is essential to an understanding of the relative position of fuel oil and the effect of the expansion in its use. The United States and Europe are the principal consumers of the various mineral fuels from which modern energy is largely derived. The competition of oil, gas, and water power with coal, which is largely a development of the last thirty years, has been partly responsible for the almost stationary world production of coal since 1913 and the depressed conditions in coal mining, particularly in the United States and the United Kingdom. In this connection, the importance of the increased efficiency in the use of coal and the development of new coal mining areas are factors that must not be overlooked. The United States has been the center of the keenest competition between the different sources of energy, since it consumes 60 per cent of the world's fuel oil and over 95 per cent of the world's natural gas, in addition to its large water power developments. The primary purpose of this section is to indicate the position that fuel oil occupies in relation to other sources of world energy. In order to compare the different forms of energy, they have been converted to short tons of equivalent coal on a rough basis, which is discussed in the Appendix, page 150.

1. ENERGY IN RELATION TO CIVILIZATION, INDUSTRY, AND TRADE

Energy resources and production are basic factors in modern economic development, machine industry, international trade, and world power. A survey of world energy consumption indicates the dominant position of the United

States and northwestern Europe. The principal centers of coal production, of the final consumption of the products of crude oil, and of water power development are found in these regions. A third fuel production area of much less importance is developing in eastern Asia. The most advanced and powerful nations of the world are the greatest consumers of mechanical energy. Modern factory organization, requiring large capital and the centralization of masses of skilled labor, has produced a most complex and highly developed social organization. International trade depends primarily on the importation of raw materials and food to the great industrial centers and the exportation of manufactured goods in exchange. The railroad and the steamship serve as the means of collecting and distributing the products of the highly specialized industrial areas. Modern navies serve to protect the essential trade routes and to maintain control of distant sources of raw material and food supply. The factory, the railroad, the steamship, and now the automobile and the motor truck are the great consumers of fuel and power.

Almost ninety-five per cent of the modern forms of energy is consumed in the north temperate zone. The remainder is about equally divided between the vast areas of the tropics and the comparatively small south temperate zone region. The small energy consumption of these latter regions is due to the less advanced industrial development and the preponderance of agriculture, the comparatively scanty population in the more advanced temperate areas, the low standard of living in the densely crowded sections of the tropics, and the milder climate, requiring little domestic heating.

2. MODERN ENERGY DEPENDENT ON MINERAL FUELS AND WATER POWER

Coal, fuel oil and gasoline, natural gas, and water power are the chief sources of modern energy. The increase in the volume of energy derived from these sources must not, however, be taken as a measure of the total net increase in world energy consumption. A considerable part of the use of these modern forms of energy represents a substitution for older

forms. The steamship has now almost entirely displaced the old sailing ship dependent on wind power. The gasoline engine is causing the less dependable windmill to disappear from the rural landscape. The automobile and the tractor are replacing the horse and other farm work animals. Coal, oil, and electricity have superseded wood and charcoal as domestic fuel in advanced and densely populated communities. The branch railroad and the river steamboat have in most cases turned from vanishing wood supplies to the more abundant and convenient coal or oil. Factory machinery has been substituted generally for human labor. Thus a considerable part of the modern increase in energy consumption must be regarded as a shift from older to newer sources. When due allowance has been made, however, for this factor of substitution, there still remains a large net increase in the total consumption of energy, derived mainly from mineral fuels and water power.

3. COMPETITION BETWEEN MODERN SOURCES OF ENERGY

The last thirty years have been marked by the development of keen competition between the different sources of energy. Prior to 1900 coal was the chief source of modern energy, and its consumption throughout the world was steadily increasing. Since 1913 the production of coal has increased but slowly, and a serious depression has developed in the older and more important centers of coal production. The depressed condition of the coal industry is due to a complicated series of new developments and not predominantly to any single cause.

The main causes of depression in the older coal-mining regions, in spite of an increasing total consumption of world energy, are:

(a) The increase in the amount of useful energy secured from a ton of coal;
(b) The competition of new coal fields;
(c) The rapid expansion of the production and consumption of oil products;
(d) The increasing supply of natural gas;
(e) The development of hydro-electric power.

(a) Increased Output of Energy from Coal

The greatest progress, in increasing the amount of useful energy secured from a ton of coal, has been the result of active research by large consumers of energy in an effort to cut the cost of production of their services or products. Public utility companies, railroads, and producers of coke and iron and steel have been particularly active. The recovery of heat from waste gases, saving the gases from by-product coke ovens, improvements in boiler efficiency, extensive use of automatic feed and control devices, and better combustion obtained through the use of powdered coal are notable developments. The development and sale of electric power by large central plants, fuel or hydro, has been a tremendous factor in fuel economy. It has meant the elimination of the smallest and least efficient power plants. The small manufacturer now prefers to buy his power rather than to attempt to produce it himself. The present fuel consumption of the public utility plant, of from one to two pounds of coal per kilowatt hour, has thus replaced a fuel consumption of from three to six pounds by the small power plant, with the result of securing the same amount of power while using only one half to one third of the coal formerly consumed. The progress made in the past ten years in the more efficient production and use of energy for industrial purposes has meant a saving of probably at least twenty-five per cent in the fuel requirements for the delivery of the same amount of energy.

(b) Competition of New Coal Fields

Increased coal production from new fields has meant decreased output and depression in the older coal mining areas. The United States and the United Kingdom have suffered most in this respect. In the United States increased production, particularly in West Virginia and Kentucky, has caused depression in the older Pennsylvania fields and has resulted in capacity for overproduction and increased competition of coal with coal. In the case of the United Kingdom, a serious depression in the coal industry has resulted from the expansion of coal mining in other countries during

and after the War and the consequent decline of coal exports to the Continent.

During the War, the Netherlands suffered from inability to secure coal and undertook an expansion in domestic coal production, which increased from 2 million short tons in 1913 to 12 million short tons in 1928. Belgium has increased its coal production from 25 million short tons in 1913 to 30 million short tons in 1928. Germany, having lost important coal producing areas to Poland and France in the territorial changes resulting from the War and confronted with the necessity of supplying its own coal needs and furnishing the reparations coal to be shipped to France and Italy, has increased the production of its remaining coal fields and in addition has developed and used the low-grade brown coals. Coal production in the areas lost to Poland and France had in 1928 reached practically the pre-war level. Poland, with coal production back to the pre-war level of 45 million short tons and with a smaller market available for it in Germany, has been seeking an export market in Scandinavian countries in competition with British coal. France is one of the best markets for imported coal. The principal French coal mines were destroyed during the War, and in the post-war period France had to secure more coal from England and Germany. The French coal mines have now been rehabilitated and are producing about 7 million short tons more than in 1913. In addition, France has undertaken an active hydro-electric development. The readjustment of boundaries among the smaller states of Europe has stimulated domestic coal production, and in practically every case production is again at or above the pre-war level. In Russia, under the new program of industrial expansion, coal production has already reached the pre-war level and in 1929 was considerably above it.

The net result of all these changes has been to increase coal production on the continent of Europe outside the United Kingdom by 60 million short tons in 1928 over the 1913 level, the lignite coals having been reduced to bituminous coal equivalent. While total consumption demands have also increased, there has been a material decline in imports from the United Kingdom, and this has been an important factor in the depression of the coal industry there.

(c) Expansion in Use of Oil Products

The expansion in the world production of crude oil, from 385 million barrels in 1913 to 1,328 million in 1928 and 1,488 million in 1929, has been an important factor in keeping world coal production at a stationary level. A rough measure of the extent of this development is to equate the heat value of oil on the basis of 3.6 barrels as being equivalent to one short ton of coal. On this basis, crude oil production may be estimated as equivalent to 107 million short tons of coal in 1913 and 369 million short tons of coal in 1928. The total crude oil output does not come into energy competition; there is a considerable shrinkage, due to losses in production and refining, and a part of the total goes into non-energy products, such as lubricants and asphalt. The estimated net consumption of the main oil products derived from crude oil that compete directly or indirectly as sources of world energy was in 1928:

Fuel oils	600	million barrels[1]
Gasoline	410	" "
Kerosene	105	" "
Total	1,115	" " [2]

[1] Barrels of 42 U. S. gallons.

[2] Crude oil used for fuel is included under fuel oils, but gasoline from natural gas is not included with the products of crude oil.

Competition of Fuel Oil

Fuel oils, including crude oil used direct, refinery gas oil, and fuel oil, represented the most direct competition in the energy group, with an equivalent to 167 million short tons of coal. Practically all the fuel oils are used in the production of heat or power and may be considered as filling a demand that would otherwise have been met primarily by coal. The fact that much of this oil is used in non-coal-producing areas means that, even though it has not actually displaced coal, the industries supplying the needs of the population in those areas would have required some other form of energy, or that goods from other producing regions using an equivalent amount of energy would have been imported, if cheap oil had not been available.

As more than sixty per cent of the world output of fuel oil is consumed in the United States, it is evident that the

competition of fuel oil has had an important effect in keeping coal production in this country at an almost stationary point. The three principal regions of fuel oil consumption in the United States are the North Atlantic states, the South Central states, and the Pacific Coast states. The keenest competition of oil with coal is in the North Atlantic region, where its extensive use has been one of the factors retarding the expansion of coal production in the Appalachian fields.

The total fuel oil consumption of Europe is over 110 million barrels a year, one half of which is produced and used in Russia. The comparatively small consumption of fuel oil in the rest of Europe, which produces more coal than the United States, indicates that the competition of oil with coal has been a less serious factor. Its use has had, however, an important bearing on the depression of the coal industry in the United Kingdom. The principal use of fuel oil in northern Europe is for naval and merchant ships. This bunker market was formerly supplied largely by British coal, and the increased use of fuel oil has caused a material decline in the bunker coal trade in British ports and in coal exports to bunker stations in other countries.

The fuel oil consumption in other regions is: (1) about 70 million barrels in American countries south of the United States, and (2) about 40 million barrels in various parts of Asia and Oceania. The use of fuel oil in these regions has supplemented the comparatively small coal production. Without the fuel oil, the domestic output of coal would have increased to a greater extent in Asia, and coal imports would doubtless have increased in South America instead of having declined. On the whole, fuel oil consumption must be regarded as having filled a large increased demand for energy, which otherwise coal would have supplied, and as having actually displaced coal in some markets.

Competition of Gasoline

The competition of gasoline with coal and water power is less direct and consequently is usually underestimated. The development of the gasoline stove was the first important step in competition in the energy field, but it is a comparatively small factor in the present situation. The internal

combustion engine, particularly in the automobile, is the dominant factor. The number of motor vehicles registered in the United States was only 3,000 in 1899, passed the million mark in 1913, and rose to about 7.6 million in 1919, 17.6 million in 1924, and 26.5 million at the end of 1929. As the total world figure for the latter date was 34.8 million, it appears that about three quarters of the motor vehicles were in the United States. Only 13 per cent of the total registration in the United States represented trucks and buses, while for the rest of the world the corresponding figure was 25 per cent, which indicated that the use of the motor vehicle for commercial transportation was of greater relative significance abroad.

The exact character of the competition of the motor vehicle in the energy field is difficult to estimate exactly. In the period of its early development it might be classed as a pleasure vehicle, and even at present a considerable part of the annual mileage of private automobiles represents non-commercial uses and a new demand for energy that would not have arisen under the older forms of transportation. On the other hand, the automobile is used largely for commercial transportation, and the increasing number of taxicabs, buses, and trucks which are primarily so used is a striking recent development. The growing importance of this factor is evident from the seriousness with which steam and electric railroads regard competition from this source, not only in the United States but in foreign countries. Numerous interurban electric lines have been entirely abandoned, and their tracks torn up, the service being replaced by bus lines. Many railroads have adopted the policy of meeting gasoline competition by owning and operating bus lines and in some cases abandoning small branch railroad lines. The effect of this competition has been especially noticeable in the short haul passenger and freight movements in regions of dense population, where it is one of the factors explaining the decrease in fuel consumption per ton mile in railroad freight movements. Gasoline must, therefore, be regarded as a serious competitor of both coal and electric power. The competition of the automobile with animal energy has been even more effective; it is responsible for the rapid dis-

appearance of the horse from American highways, both for pleasure riding and for industrial transportation. While automobile competition has been most highly developed in the United States, the increasing use of motor vehicles in European countries is rapidly extending its effects throughout the industrial states of the Western World.

The rapid development of commercial air transportation will further extend the field of gasoline competition, although in terms of quantity consumption the airplane is still a minor factor when compared with the automobile. It should be noted also that the high energy efficiency attained in the internal combustion engine gives gasoline, in comparison with coal, a fuel value per barrel much higher than that of fuel oil burned under boilers.

The difficulty of determining the exact extent of the commercial competition of gasoline with other forms of energy is too great to warrant further discussion in the present study, which is primarily restricted to fuel oils. In conclusion, however, it may be remarked that, since the movement for the conservation of oil necessarily implies reduction of the percentage of fuel oil consumption and increase of the percentage of gasoline consumption, the growing consumption of gasoline will tend to shift the center of competition among the products of crude oil in the energy field from fuel oil to gasoline.

Competition of Kerosene

The total consumption of kerosene is relatively much smaller. Its use as a source of light is confined mainly to backward countries, where it fills a field formerly unoccupied or has displaced vegetable and animal oils. Electricity and gas for lighting and cooking are displacing kerosene and restricting its use. As a result, a larger percentage of the crude oil that was once turned into kerosene is now being converted into motor fuel, and more of the kerosene itself is being used as a motor fuel to operate tractors and farm machinery. Kerosene has had little competitive effect on other sources of modern energy and is a factor of decreasing importance, except as it is entering the motor fuel field, where its chief effect has been the displacement of animal

power. If heavier types of motor fuel should come into general use, kerosene may ultimately merge with gasoline from the standpoint of consumption.

(d) Increasing Supply of Natural Gas

The consumption of over 95 per cent of the world's natural gas in the United States is an important factor in the competitive energy situation not found in other countries. Canada, Russia, Rumania, and a number of other oil producing countries consume the remainder of the world supply. In all these countries the natural gas output is relatively small and is used mainly in oil field operations. The consumption of natural gas in the United States increased from 582 billion cubic feet in 1913 to 746 billion in 1919, to 1,568 billion in 1928, and to 1,917 billion cubic feet in 1929. Assuming 23,000 cubic feet of natural gas to be roughly equivalent to a ton of coal, output has increased from 25 million short tons of coal equivalent in 1913 to 68 million tons in 1928 and to 83 million tons in 1929.

Natural gas must be distributed by pipe line, and consequently its competition is limited by the radius of profitable distribution. Prior to 1927 the larger part of the output was used within a limited radius of the point of production; transportation beyond 250 miles was unusual. Since then long distance pipe lines up to 450 miles have been constructed, others are building, and a line 950 miles long is being considered to serve the Chicago area. The long-distance distribution, however, is chiefly in connection with new gas fields more distant from the centers of main energy consumption.

Natural gas production in the older regions of Pennsylvania and Ohio has been declining. The expansion in output has come from Louisiana, Texas, and California, regions in which fuel oil is a predominant source of energy. In fact, the chief competition of natural gas has been with oil, and its most important effect has been to release more oil for sale. The total increase in natural gas consumption from 1919 to 1928 was 822 billion cubic feet. Of this increase, 404 billion was for field use in the production of oil and

gas, 88 billion for fuel used by oil refineries, 140 billion for fuel and power in other industries, 65 billion for domestic use, and 125 billion for the manufacture of carbon black. The increase of consumption has thus been greatest in the use for oil company purposes and for other industrial uses in regions where fuel oil is available. Estimated production in 1929 shows a further increase of about 22 per cent over 1928. New pipe lines have extended the area of distribution and may materially change the character of both domestic and industrial consumption.

In the Middle West and the South the long-distance gas lines to Denver, St. Louis, Birmingham, and Atlanta have extended its competition into coal areas. In California completion of a line to San Francisco has displaced artificial gas produced from oil. The construction of expensive long distance pipe lines is an indication that large supplies of natural gas are available and that its competition will continue for a considerable period.

The recent rapid increase in the natural gas supply has thus added a new competitive factor for both fuel oil and coal, and has been one of the factors in the declining trend of fuel oil prices. The extension of the market for natural gas is so recent that it is still difficult to estimate its full effect.

(e) Development of Hydro-Electric Power

The development of world hydro-electric power shows a steady upward trend. This has been due largely to long-distance transmission, which has made it possible to serve consumers in localities distant from the generation of power but offering advantages from the standpoint of labor and markets. Many of the best and cheapest water power sites accessible to consumers have now been developed. A large portion of the undeveloped potential power is in regions far from energy markets. The original installation cost of hydro-electric plants is considerably greater than that of fuel-electric plants. The rapidly increasing efficiency of fuel plants, moreover, has reduced the coal equivalent of water power installations. The average consumption of

coal per kilowatt hour of electricity produced, in the public utility plants of the United States, has decreased from 3.2 pounds in 1919 to 1.8 pounds in 1928 and to 1.7 pounds in 1929. Because of these factors, fuel-electricity is increasing more rapidly than hydro-electricity. The coal equivalent of the world's developed water power in 1928, 39 million horsepower, or 29 million kilowatts, is probably about 117 million short tons on the basis of the amount of coal it would take to produce the same amount of electricity at the fuel efficiency attained in 1928. If fuel efficiency had not improved and had remained on the 1919 basis, the coal equivalent would have been almost twice as great. In short, a given amount of water power replaces much less coal than formerly.

A large part of the world's water power has been developed in countries or parts of countries lacking other adequate sources of energy. In Norway, Sweden, Switzerland, Italy, and southern France, coal was lacking and had to be transported long distances. In the United States the chief water power developments are in New England, in the Great Lakes region, in the South Atlantic states, and in the Pacific Coast states. In these areas local coal deposits are inadequate, and long freight hauls are necessary to import coal. The principal water power developments in Canada are in the fuel-less zone of Ontario and Quebec, where coal is largely imported from the United States. In Japan water power development has supplemented local coal production.

On the whole, water power may be considered as an important supplementary source of energy of particular importance in the development of areas more or less distant from coal supplies. However, the development of water power has undoubtedly occupied a field much of which would otherwise have been taken by coal and in some cases has actually displaced coal imports or caused them to remain stationary. In the Pacific Coast region water power has had to compete directly with fuel-electricity produced from oil. The abundance of cheap oil fuel has retarded the use of hydro-electric power in this section.

The principal world water power developments are in the United States and Canada and Europe. In these two areas

water power has been of about equal importance as a competitive source of energy and has been an added factor that has contributed to the stationary demand for coal. The almost universal development of large central fuel-electric power stations, with greatly increased efficiency in fuel utilization, is making coal a more formidable competitor of water power and may eventually result in retarding the growth of the latter, particularly as many of the remaining water power sites will involve greater difficulty and expense in development.

4. MOST ACTIVE REGIONS OF ENERGY COMPETITION AND RESEARCH

(a) The United States

The United States is the largest producer and consumer of energy and is the field of greatest competition between the different sources of energy. In 1928 the United States produced 39 per cent of the world's coal, 68 per cent of the crude oil, 96 per cent of the natural gas, and 35 per cent of the hydro-electric power. Proportionate consumption was almost as great. Exports of coal would about be balanced by coal taken from storage, and a net export of oil products would reduce the oil figure to 63 per cent. The production of coal has remained almost stationary since 1913, in consequence of the increase in fuel efficiency and the competition of other forms of energy. During the same period the production and the consumption of fuel oils, gasoline, natural gas, and hydro-electric power have expanded greatly.

The large-scale mass production characteristic of the United States involves fuel and energy consumption by great corporations, which have the resources to carry on extensive research in fuel efficiency and find such research profitable. The large and varied energy resources of the United States have resulted in very cheap fuel, on the whole, and in the pre-war period this factor served to retard, to some extent, the interest in fuel conservation. During the War and post-war periods, however, fuel costs increased, and the higher prices served to stimulate fuel research. The public utility and railroad companies have been par-

ticularly active in their interest because of the importance of fuel costs in their operating expenses. The shift from beehive to by-product coke ovens has resulted in a general recovery and use of gases rich in heat and by-products that formerly went to waste. Thus the interest of both the competitive sellers of different sources of energy and the large consumers has resulted in rapid progress in fuel efficiency and economy, especially in the last ten years.

(b) Europe

Europe is the second great region of energy consumption, particularly the manufacturing countries in the northwestern part of the continent near the great coal fields. Competition between the various sources of modern energy has been less keen than in the United States. In 1928 Europe produced 50 per cent of the world's coal, 9 per cent of the crude oil, 2 per cent of the natural gas, and 39 per cent of the hydroelectric power. Total energy consumption was larger than production by reason of the heavy imports of oil products. Total coal exports from the Continent do not exceed 8 or 9 million tons a year. Total consumption of petroleum products was about 235 million barrels, or over 100 million barrels greater than the production of crude oil, which was 125 million barrels. The percentage of world oil consumed was about 16 per cent, as compared with only 9 per cent production of crude oil. This percentage of oil consumption is only about one fourth that of the United States. Natural gas production is relatively small, and it is consumed mainly in oil field operations. The amount of water power developed is somewhat larger than in the United States.

Coal occupies a more important position in Europe than in the United States and has had to meet less competition from other sources of energy. The principal factors in the European coal situation are the general increase in the efficiency of fuel utilization and the increased coal production on the Continent, largely at the expense of British coal exports. Interest and research in fuel efficiency have developed along lines somewhat different from those followed in the United States. The division of the Continent into

many separate countries has resulted in attempts to develop local energy resources and consequently in great diversity of interest. Mass production by large corporations is less prevalent, and the activity of private research is less. The greatest interest has been shown in the development and utilization of low-grade coals and even of peat. The necessity of importing large quantities of oil products, which generally sell at much higher prices than in the United States, has led to greater research for oil substitutes, particularly for motor fuels.

The competitive problem of the United Kingdom has centered in the loss of coal markets and the depression of coal mining, and also in the necessity of lowering industrial costs in order to maintain the export trade in the world's markets. The development of greater efficiency in coal mining and the consolidation of mining interests have been carefully studied. Great interest has been shown in means of increasing the efficiency of coal, and much attention has been given to the carbonization of coal and the recovery of its by-products. There has been an expansion of the domestic oil-refining industry based on imported crude oil.

Germany has been actively developing its low-grade brown coal deposits and studying the problems of their utilization as powdered coal and in the form of briquets. The production of substitute motor fuel from the treatment of coal and from the by-products of coking and carbonization has made rapid progress, although the total amount so produced is still relatively small.

France is keenly interested in energy problems, because of large coal and oil imports and expanding industrial demands for energy. Accordingly France has undertaken an active program of water power development, has rehabilitated and modernized the coal mines, has increased the by-product recovery from coking coal, and has placed restrictions upon oil imports with the object of encouraging domestic oil refining. Government regulations require some domestic alcohol from the beet sugar and wine industries to be used in motor fuel mixtures.

Italy is carrying forward a program of water power development. As this country has no important coal deposits, it

is necessary to import fuel for the expanding industrial needs of the population. Italy's chief concern lies in increasing fuel efficiency and in securing fuel imports, either coal or oil, from the cheapest sources. A company, backed by the government, has been organized to purchase oil products, and regulations have been adopted to compel the mixture of alcohol, a by-product of the wine industry, in motor fuel. Italy is increasing the importation of oil products from Russia and is even importing some coal from the same source.

The smaller countries of central Europe have considerable supplies of lower-grade coals and are interested in their utilization. Wherever water power is available there is an active interest in its development.

On the whole, European countries are becoming generally aroused to the importance of energy problems and the advantages of large-scale industrial enterprise, as related to national economic development. Interest is largely centered on national needs and the development of domestic resources, in order to become as nearly independent in energy supply as possible.

5. RECENT REVOLUTIONARY CHANGES IN ENERGY SUPPLY AND UTILIZATION

Fundamental changes are taking place in the utilization of world energy and in the sources of its supply. The shortage of fuel and the much higher prices prevailing during and after the War have stimulated progress in the efficient utilization of energy, particularly coal. The electrification of industry has substituted the purchase of electric power from large central plants for the less efficient production of power by small individual plants. The large plants make possible a better balanced load factor and a more complete utilization of equipment, as well as greater fuel economy. The "giant" and "super" power projects, for the interconnection of distributing systems over wide areas, have brought about further widespread expansion of the use of electric power.

Another notable change has been the increasing substitution of oil for coal in the fueling of merchant and naval

vessels. Prior to the War the use of oil as a bunker fuel for merchant ships was comparatively unimportant, except on the Pacific coast of the United States and in the internal trade of Russia. The increasing supplies of available fuel oil, together with replacements of merchant ships destroyed by the submarine campaign, have resulted in an increase of the tonnage of merchant ships equipped for oil-burning from 3 per cent of the total world gross tonnage of steamships in 1914 to 37 per cent of the corresponding total, including motor ships, in 1928. The navies of the great powers are now practically all on an oil-burning basis. The world fuel oil consumption for merchant and naval vessels now totals close to 175 million barrels a year, about one half being supplied in United States ports. The motor ship, equipped with Diesel engines, is the most important recent development in ship construction and brings with it greater economies in oil consumption. The increasing competition of petroleum products—fuel oil and gasoline—in the world energy market since 1914 is most significant. With the increasing ability to convert fuel oils into gasoline, the future trend of fuel oil supply will vary with the relation of increasing gasoline demand to a surplus or a shortage in world crude oil production.

The recent rapid expansion of natural gas supply in the United States and the steady expansion of water power development in the United States, Canada, and Europe, particularly in France and Italy, are two other factors of prime importance.

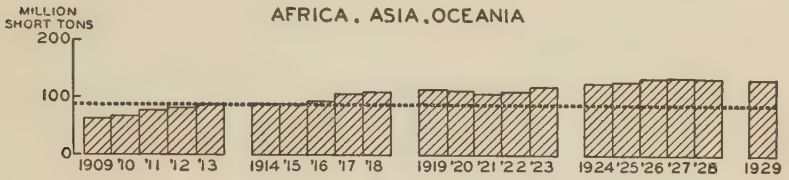
The cumulative effects of these changes in world energy supply have been most noticeable in the depressed condition of the coal industry in the United States and in the United Kingdom. During the disturbed conditions of the War period and the post-war period up to 1925 and 1926 the full significance of the changed situation was not clearly recognized. The small output of the coal mines in the devastated area of France, the large fuel demands for reconstruction, the interruption of coal production by serious strikes in the United States and in the United Kingdom, and the decline in German coal production during the occupation of the Ruhr district combined to prevent a normal output from all

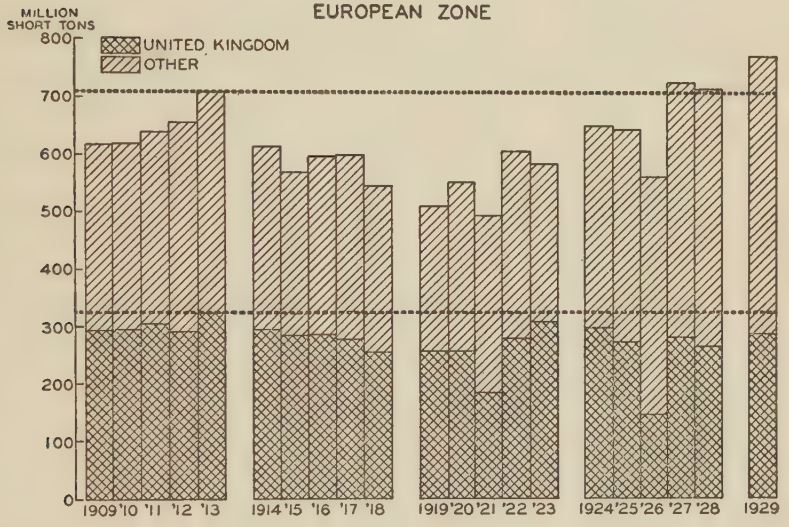
the coal regions in any one year. But with the return to normal production capacity in all the most important coal fields the problem that confronts the coal industry has become acute.

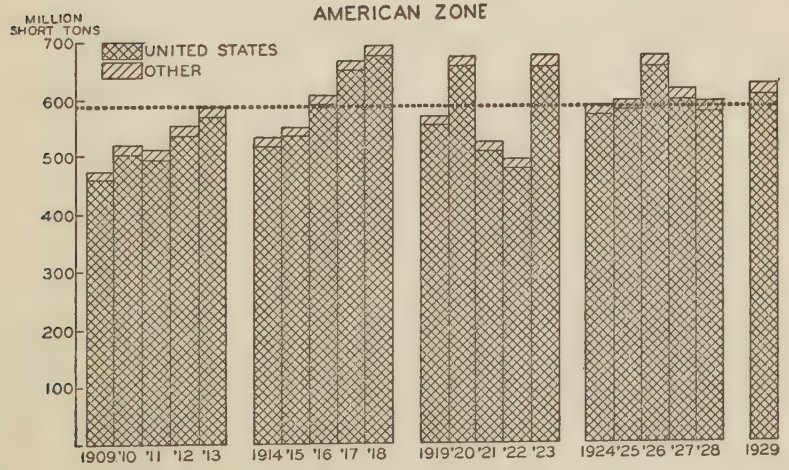
The various changes in energy supply and utilization indicated in this brief summary are so far reaching and complicated in their effects and interrelations that they may well be termed revolutionary. It has been the primary purpose of this introductory chapter to present an outline picture of the whole problem and to indicate the present position of fuel oil in relation to total world energy supply, before proceeding to a more detailed study of the trend of its production and use.

World Regional Coal Production, 1909–1929

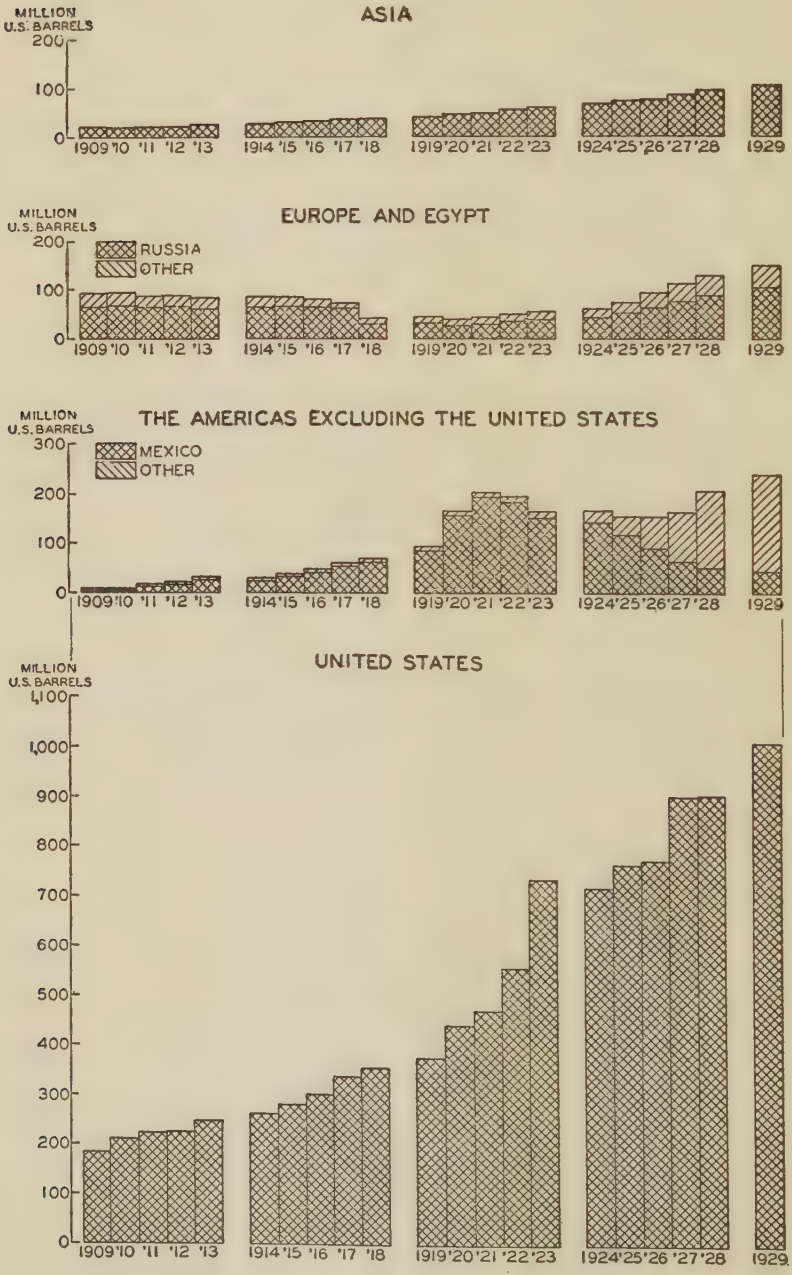
Millions of short tons. Lignite reduced to equivalent coal on the basis of 4.5 tons of German brown coal = 1 ton bituminous. Other lignites, 2 tons = 1 ton bituminous.





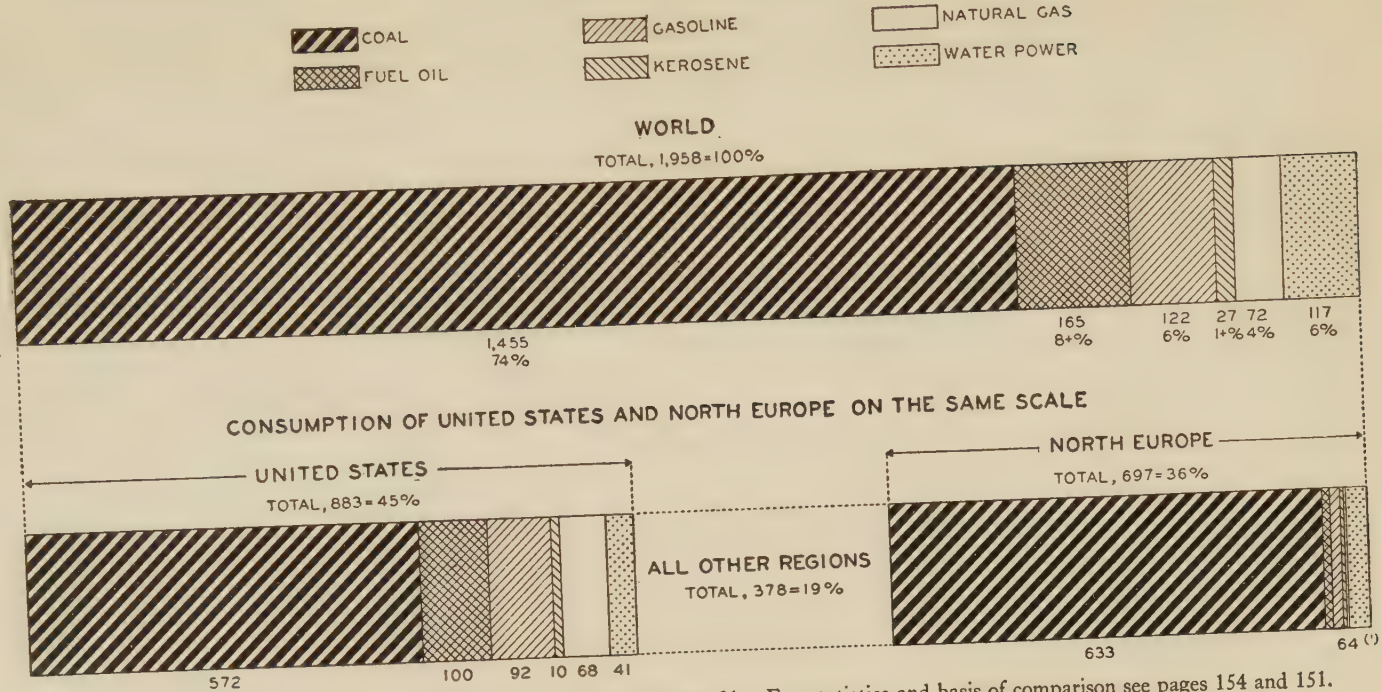


WORLD PRODUCTION, CRUDE PETROLEUM, BY REGIONS, 1909–1929



World Energy Consumption in Terms of Equivalent Coal, 1928

(All figures in million short tons)



[1] Fuel oil: 12; gasoline: 16; kerosene: 4; natural gas: 1; water power: 31. For statistics and basis of comparison see pages 154 and 151.

PART II

WORLD SUPPLY AND CONSUMPTION OF FUEL OILS

SUMMARY

PART II discusses the world fuel oil situation and is subdivided into four main sections.

Section 1 takes up the relation of fuel oil to crude oil. Improvements in refining methods have resulted in a decline in the direct use of heavy crude oils for fuel without refining, and the status of such oils has been changed from a necessary by-product to a potential source of gasoline. Consequently, in case of a world shortage in crude oil supply, the increasing demand for gasoline would be met by converting the oils now sold for fuel purposes.

Section 2 discusses the trend of total world production of crude oil, the regional changes in the sources of supply, and the international movement of crude oil to its final destination for refining or consumption. The total supply of fuel oil available will depend largely on the relation of increasing gasoline demand to a surplus or a shortage of crude oil production. The regional consumption of fuel oil bears a close relation to the location of refineries, which to an increasing extent are determining the local availability of fuel oils. The increasing percentage of gasoline output will tend further to shift the location of refineries to centers of large population and consumpton and thus to concentrate the residual output of fuel oils in the same locations. The topping of oil in producing regions, to secure a local supply of fuel oil, will further decline in those areas in which a scarcity of fuel oil restricts consumption.

Section 3 summarizes the apparent world consumption of the products of crude oil. It presents a balance sheet of world crude oil production and the total final products in the forms in which they reach the market. The total amount of oil used for fuel purposes is indicated, and its relation to other refined products is shown. Approximately one half of the total oil consumed in 1928 was used for fuel purposes. Gasoline and kerosene account for about 45 per cent of the total products and have a distinct bearing on the competitive

energy situation. The remaining products may be considered as either in the non-energy group or of relatively small importance.

Section 4 takes up the distribution and final consumption of fuel oils, by countries and regional world fuel oil markets, and indicates the factors that determine such distribution. The relative predominance of the United States as a consumer of fuel oil is briefly indicated, and the consumption in other world markets is discussed.

1. RELATION OF FUEL OIL TO CRUDE OIL

The total supply of oil used for fuel purposes includes the crude oil used direct for fuel without refining and the refinery output of gas oil and fuel oil. Prior to 1900, under earlier methods of refining and with a large demand for kerosene, the light crude oils in the Appalachian fields of the eastern United States produced very little fuel oil and only a comparatively small amount of gas oil. After 1900 the development of heavy crude oil production in California, Texas, and later in Mexico made available large quantities of oil from which only a small per cent of lighter products could be obtained by the prevailing methods of refining. As a result, large amounts of these crude oils were used direct for fuel or after a simple topping process. The medium grades of crude oil produced in the Mid-Continent region of the United States were generally refined, but produced large amounts of gas oil and fuel oil as residual by-products after the available gasoline and such kerosene and lubricants as the market required had been taken out. The result of these two factors was a large and increasing supply of fuel oils from 1900 to 1914.

Since 1914 the introduction of new methods of refining, stimulated by a growing demand for gasoline, has made it possible to convert the heavier crude oils and to secure from them a larger yield of lighter oils. This development has resulted, in recent years, in a steady decline in the amount of crude oil used for fuel without refining and in a rapid increase in the per cent of gasoline secured from oils that would formerly have been converted into kerosene or gas oil

and fuel oil. The effect of these "cracking" processes[1] in changing heavy oils into gasoline may be further extended by the recent development of a new method of treatment called hydrogenation. The status of heavy fuel oils has thus been changed from a necessary by-product, to be sold as a fuel, to a potential source of gasoline. The average output of gasoline obtained from all crude oils in the United States has risen from about 18 per cent in 1914 to 39 per cent in 1929, and it could be increased to 60 per cent or more if the new methods were applied to all the crude oil refined. Such an increase in the gasoline output would result in a corresponding decrease in fuel oil production. These changes in the relation of fuel oil to crude oil are discussed in more detail later in this section, and their significance in relation to an ultimate decline in the per cent of fuel oils available is indicated.

(a) Products of "Straight Run" Refining

The essential principle of the older or "straight run" method of refining was to put the crude oil into closed retorts or stills and heat it. Heat vaporized the lighter parts of the oil, which, on cooling, would return to a liquid state. The various products were separated by cooling and condensing the vapor and diverting them to different storage tanks. The lightest or most volatile group of products included gasoline, benzine, and naphtha. As the temperature in the still increased, heavier oils were vaporized. The lightest of these heavier oils was kerosene, or illuminating oil. Furnace distillate, gas oil, and Diesel oil made up the next group of products. The residuum, or heavier oil remaining after the removal of gasoline, kerosene, gas oils, and distillates, could be used direct as fuel oil or treated in various ways to produce different grades of lubricating oil, wax, asphalt, and road oils. When the oil was completely refined, the final product was either asphalt or petroleum coke. As the market demand for lubricants, wax, and asphalt was not sufficient to absorb the large quantities of these products which the residual oil was capable of yielding, a considerable part of the

[1] See p. 30.

latter was not converted at all, but was left as a by-product to be disposed of for heavy fuel purposes in competition with coal.

(b) Small Output of Fuel Oils Prior to 1900

Under this "straight run" method of refining, the percentage of the various products secured was fixed by the natural content of a given type of crude oil. Light oils contained more gasoline and kerosene, and heavy oils, much less. The crude oils produced in the United States up to 1900 were generally light, or high quality, oils. Kerosene, lubricants, and wax were the products most largely in demand. As much kerosene as possible was produced. There was little demand for gasoline.

Consumption of oil for fuel in the United States prior to 1900 was comparatively small. In 1899 the total production of crude oil in the United States was 57 million barrels, but 53 million barrels of this came from the Appalachian and Lima-Indiana fields, whose output of high grade oil was largely turned into refined products. At this time the average distillation of Pennsylvania crude oil yielded 76 per cent kerosene, 11 per cent gasoline and naphtha, and 3 per cent lubricants, which left only 10 per cent for fuel oil and losses. The high grade of the crude oil and the dominant demand for kerosene resulted in a small output of fuel oils. California was the chief producer of heavy crude oil, but its total production in 1899 was only 2.6 million barrels. The total apparent consumption of crude oil in 1899 was approximately 56 million barrels, of which, according to the United States census in 1899, 52 million barrels were refined. This would indicate that 4 million barrels were used direct for fuel. There must be added to this 7 million barrels of gas oil and fuel oil; the total consumption of oil for fuel was thus about 11 million barrels—4 million barrels of crude oil used direct and 7 million barrels of refinery products. A large part of this total was used by the oil industry itself as fuel in the oil fields, fuel for pipe lines, and fuel for refining operations. Competition of oil with other fuels had been a negligible factor prior to 1900.

(c) Expansion of By-Product Fuel Oil, 1900–1914

In the period 1900–1914 new oil fields were developed in California, Texas, and the Mid-Continent area. Crude oil production and supply increased enormously. The development of gas and electric lighting resulted in a slower increase of the demand for kerosene. The growing use of the automobile caused a rapid increase in the demand for gasoline. The demand for lubricants, wax, and asphalt increased slowly. Many of the new crude oils produced were of a heavy type with small gasoline content. In order to meet the growing demand for gasoline, larger quantities of crude oil were refined, with a growing volume of by-product residual oil, which could find a market only for fuel purposes. Much of the heavy oil from the Texas Gulf Coast and California was used direct for fuel without refining.

The production of heavy crude oil in California increased steadily during this period, from 2.6 million barrels in 1899 to 55 million barrels in 1909. The heavy oils of the Gulf Coast region of Texas and Louisiana first became important in 1901, with a production of 3.6 million barrels. In 1902 the production of this region jumped to 18 million barrels and in 1905, to 37 million barrels; then declined to 11 million barrels in 1909. The Mid-Continent field increased its production from less than 1 million barrels in 1899 to 51 million barrels in 1909. The oils from the latter field were of higher refinable grade and served to increase the supply of gas and fuel oils.

Importation of crude oil from Mexico into the United States began in 1910, reached a total of 17 million barrels in 1913, and increased very rapidly after 1915. The bulk of the Mexican oil was of a heavy type and was used largely as fuel oil. The increasing supply of Mexican oil served to stimulate fuel oil consumption in the Atlantic Coast region of the United States and in Europe and South America. Increasing oil production in Asia also insured a larger supply of fuel oil in that region. With large world-wide supplies of fuel oil available in increasing amounts, interest in its use as a marine fuel for naval and merchant ships developed rapidly, and by 1914 fuel oil consumption was becoming more

wide-spread and no longer restricted mainly to the oil-producing regions of California, the South Central part of the United States, and the interior of Russia.

(d) Development of "Cracking"

The consumption of gasoline in the United States increased over twelve-fold from 1914 to 1929, from about 30 million barrels a year to 376 million. Under the old "straight-run" methods of refining, with a production of 18 per cent of gasoline from a barrel of crude oil, it would have taken more than twice the amount of crude oil actually refined in 1929 to have produced this output of gasoline. While part of this increased gasoline output has been due to the recovery of gasoline from natural gas, to improvements in "straight run" methods, and to the introduction of the tube still, the larger part has resulted from improved refinery methods using greater heat and pressure in the refinery still, which are generally described by the term "cracking." The additional heat and pressure convert the heavier oils into a larger per cent of lighter oils suitable for motor fuel. By thus treating either gas oil or fuel oil 40 or 50 per cent of the oils treated has been recovered as gasoline, and the average final output of gasoline per barrel of crude oil refined in the United States has been increased to 39 per cent in 1929. As previously stated, if all of the heavier oils produced were subjected to this process, the total gasoline recovered might rise to 60 per cent or more.

The active development of modern "cracking" methods began about 1912–1914. The production of gasoline by such methods in 1918 is estimated at 11 million barrels; in 1929 the production was 144 million barrels. A large part of this increased gasoline output has been derived from the treatment of the intermediate distillates and, to a lesser extent, the heavier fuel oils. Further development of "cracking" would cut much more heavily into the percentage of fuel oil now produced.

Commercial testing of a new process called hydrogenation is under way. In addition to increasing the heat and pressure, hydrogen is introduced into the stills and furnishes

material for combination with the oil constituents to produce much larger percentages of the lighter oils. It is claimed that by this method practically all of the crude oil could be turned into lighter products.

The effect of these new methods on the supply of heavy fuel oils has been modified by the enormous recent increase in the world production and supply of crude oil, and in consequence of this increase, notwithstanding the possibility of turning a larger per cent of crude oil into gasoline, about 50 per cent of the world's oil output in 1928 was still consumed as fuel oil.

(e) Changed Status of Fuel Oil

Fuel oil has distinctly changed from an unavoidable by-product of oil refining to a potential source of gasoline. Under recently developed conditions, whereby it is possible to convert a large per cent of fuel oil into gasoline, the future supply of fuel oil is largely dependent on the relation of total world crude oil production to gasoline demand. Fuel oil has in the past been the by-product of refining methods unable to turn it into more valuable products. In the future fuel oil supply will be determined primarily by the available supply of crude oil. The present overproduction of crude oil has been occasioned primarily by competitive drilling in fields divided among small owners, particularly in the United States. The majority of oil fields outside the United States are either controlled by large private companies or by governments. The difficulty of controlling production in the United States, the rapid expansion of Venezuelan production, and the policy of the Russian Soviet Government in increasing oil production and export are largely responsible for present world overproduction of oil. So long as these conditions continue, the production of a larger percentage of gasoline from crude oil by new methods will be retarded, and the supply of fuel oil may be further increased. The use of new methods of oil treatment, however, is steadily spreading, due to the more uniform and better quality of motor fuel produced. If the output of crude oil should become stationary or decline, either through restriction or through natural falling off in production, the percentage of gasoline

produced would increase, and the percentage of fuel oils would decline.

The present known world supplies of crude oil seem to be greater than at any previous time. There is no apparent likelihood of an immediate oil shortage. It is becoming more essential, however, to consider the effect of a possible decline in fuel oil supply, since the status of fuel oil has changed from a by-product to that of a potential source of gasoline.

2. WORLD PRODUCTION AND DISTRIBUTION OF CRUDE OIL

An understanding of world crude oil production and distribution for refining is essential to an analysis of fuel oil supply and consumption for two reasons, apparent from the foregoing discussion. (1) The direct use of crude oil for fuel is rapidly declining, and the greater part of it is now refined. Thus the final distribution of crude oil and the location of the refining plants determine the points at which fuel oil becomes available for use and distribution. Long-distance transportation of fuels is expensive, and in a highly competitive energy market there is constant pressure to reduce distribution costs. Although fuel oil is readily transported for long distances by tank steamers, the tendency is for the larger part of the output to be consumed near the point of production. (2) Fuel oil is rapidly ceasing to be a necessary by-product of oil refining. New processes now make it possible to convert a larger percentage of gas and fuel oils into gasoline. The extent to which this is done, thereby reducing the quantity of fuel oil available for consumption, is largely dependent on the amount of crude oil produced. In a period of oversupply of crude oil, such as exists at the present time, fuel oil may be abundant, and its use may increase. In case of a world shortage of crude oil, the supply of fuel oil available would be greatly curtailed.

World crude oil production has been divided into two main zones, the American and the Eurasian, between which there is little movement of crude oil. In the American zone the increasing production in the United States, Venezuela, and Colombia is the outstanding development. In the

Eurasian zone the expansion of Russian production and export has been the greatest factor in the increased supply. The excess crude oil production in the areas named has maintained and even increased the amount of oil used for fuel.

WORLD CRUDE OIL PRODUCTION[1]

Millions of barrels=42 U. S. gallons

Country	1899	1904	1909	1914	1919	1924	1928	1929	Change 1929
United States	57	117	183	266	378	714	901	1,007	106
Canada	1	1	0	0	0	0	1	1	0
Mexico	0	0	3	26	87	140	50	45	−5
Venezuela	0	0	0	0	0	9	106	137	31
Colombia	0	0	0	0	0	0	20	20	0
Trinidad	0	0	0	1	2	4	8	9	1
Peru	0	0	1	2	3	8	12	13	1
Ecuador	0	0	0	0	0	0	1	2	1
Argentina	0	0	0	0	1	4	9	9	0
I. Total, American Zone	58	118	188	296	472	880	1,108	1,244	+136
Russia	66	79	66	67	32	45	88	103	15
Rumania	1	4	9	13	7	13	31	35	4
Poland	2	6	15	6	6	6	5	5	0
Other Europe	0	0	1	1	1	1	1	1	0
Egypt	0	0	0	1	2	1	2	2	0
Persia	0	0	0	3	10	32	43	42	−1
Iraq	0	0	0	0	0	0	1	1	0
India	1	3	7	7	9	8	9	8	0
Dutch East Indies	2	7	11	11	16	20	32	38	6
Sarawak	0	0	0	0	1	4	5	5	0
Japan	1	1	2	3	2	2	2	2	0
Sakhalin	0	0	0	0	0	0	1	1	0
II. Total, Eurasian Zone	73	100	111	112	84	134	220	244	+24
World Total	131	218	299	408	556	1,014	1,328	1,488	+160

[1] All figures are given in round numbers to the nearest million. The totals given are correct, although the actual addition may vary by one or two million because the figures added are round numbers. Figures for 1929 are taken from the United States Bureau of Mines, Annual Petroleum Statement, No. P. 69.

(a) TREND OF WORLD CRUDE OIL PRODUCTION

The total production of oil is rapidly expanding. It is noteworthy that no serious world shortage of oil has yet occurred.

In the case of a product the supply of which is so irregular and difficult of determination, this is remarkable. The character and the extent of most mineral deposits can be determined with some approach to accuracy, and mining development can be adjusted to meet the market requirements. In the case of oil constant exploration and the drilling of thousands of wells in untried territory are essential to keep up with increasing demands. Flush production from new flowing wells is generally of short duration. The enormous total production now required can be maintained only by constantly bringing in new fields or by drilling old fields to a greater depth. In the past fifteen years the discovery of a half-dozen small fields of a few square miles in area, producing hundreds of millions of barrels of oil, has meant the difference between world surplus or shortage. The advocate of oil conservation is actuated largely by the thought of what might occur if we failed to locate enough additional rich fields in the future. Greater scientific knowledge of oil deposits and more accurate methods of exploration have removed some of this apprehension, but the problem still remains a serious one.

In the thirty years from 1899 to 1928 world crude oil production increased from 131 million barrels to 1,328 million, with a further estimated increase of 160 million barrels in 1929, making a total for that year of 1,488 million barrels. This eleven-fold increase in production has not, however, been uniformly distributed over the period. Crude output increased 168 million barrels from 1899 to 1909, 257 million from 1909 to 1919, and 932 million from 1919 to 1929. The principal stimulus to the world-wide effort to increase output in the latter period has been the enormous expansion of the demand for gasoline.

In 1928, after deducting all losses in production and refining and changes of oil in storage, the net world consumption of oil products in their final form was over 1,200 million barrels, of which gasoline represented about 35 per cent and fuel oils—crude, gas, and fuel—about 50 per cent. The development of the automobile has made gasoline the product of greatest importance. While a larger quantity of fuel oil is used, it could more readily be replaced by coal, while as

yet no adequate substitute, in sufficient quantities, is available for gasoline. Crude oil production for the United States in 1929 was 106 million barrels greater than in 1928. This production has been in excess of consumption. Stocks of both crude oil and refined products have increased and have given rise to serious discussion of restriction and control of output.

(b) Regional Changes in Production

Important changes have taken place in the relative position of the chief oil-producing countries since 1919, which may be considered for the two major zones, the American and Eurasian. Only a negligible quantity of crude oil is exported from one zone to the other, although there is a large export of refined product moving from the American zone to both Europe and Asia. From the standpoint of fuel oil this is particularly important because of the tendency, previously noted, for the larger part of the fuel oil to be consumed in or near the regions where refining takes place.

American Zone

In 1928 the American zone produced 1,108 million barrels of crude oil, or 84 per cent of the world total. This represents an increase of 636 million barrels over 1919, when the production was 472 million barrels. Canada produces less than 1 million barrels of crude oil, but imports a considerable amount, mainly from the United States, for use in its refineries. From the standpoint of production Canada may be left out of consideration, and the American zone may then be subdivided into two sections, the United States and the other American countries to the south. In 1928 the United States produced 901 million barrels, and the other Americas 207 million barrels, of which 80 million barrels were exported to the United States for refining. The great bulk of the increase in production of the zone since 1919 has taken place in the United States, which in 1928 produced approximately two thirds of the world output and over four fifths of that of the entire American zone. Of the other countries, Mexico reached a maximum production of 193 million barrels in 1921 and has

since declined rapidly to 50 million barrels in 1928 and to 45 million in 1929. The decline in Mexican production has been almost entirely offset by the advance of Venezuela and Colombia from a negligible production in 1920 to 126 million barrels in 1928 and 157 million in 1929. Smaller increases in production have taken place in Trinidad, Peru, and Argentina, but, as their total production was only 30 million barrels in 1928 as contrasted with 6 million in 1919, they are a comparatively small factor in the total situation.

The most significant changes in oil production in the American zone have been the large increases in California, Texas, and Oklahoma, with the most rapid advance in production in 1923, and an almost coincident decrease in Mexican production. The decline in United States imports from Mexico served to balance our increased production and prevent an oversupply. The rapid expansion of Venezuelan and Colombian production in the last three years, with still further increase probable, has increased our imports of crude oil and, together with our own increasing production, has contributed to current overproduction. A large part of the peak output of Mexico was a heavy crude oil, much of which was used direct for fuel and served to stimulate extensive fuel oil consumption on the Atlantic coast of the United States and in Europe. The decline of the Mexican crude oil output has shifted the source of supply of fuel oil to the increasing refinery output in the United States and in the Netherlands West Indies, where new refineries handled about 50 million barrels of crude oil from Venezuela in 1928 and are being equipped to handle almost twice that amount.

Eurasian Zone

In the Eurasian zone, Europe-Egypt-Asia, total production in 1928 was 220 million barrels of crude oil, or 16 per cent of the world output, as contrasted with a production of 84 million barrels in 1919. The small production of 1919 was due to minimum production by Russia in that year, and a considerable part of the increase in 1928 is the result of rehabilitation of Russian production rather than of actual new oil field development.

The principal producing countries of the Eurasian zone in 1928 were Russia, 88 million barrels; Rumania, 31 million barrels; Persia, 43 million barrels; and the Netherlands East Indies and Sarawak, 37 million barrels. Production in Poland, Egypt, India, and Japan is comparatively small, being mainly for home consumption, and has not shown a tendency to increase. While production has increased in all the leading countries, the increase has been in the nature of a steady expansion reflecting a large degree of centralized control in production and distribution. The most rapid increase is now taking place in Russia.

European crude oil production in 1928 was 125 million barrels, of which Russia contributed 88 million, Rumania, 31 million, Poland 5 million, and other countries, about 1 million. The larger part of the crude oil produced in Europe is consumed or refined in the country of production. In 1928 Russia exported only 1 million barrels of crude oil, and Rumania was credited with 2 million exports, which apparently consisted of fuel oil for re-treatment. These Russian and Rumanian exports supplied small refineries in Czechoslovakia, Hungary, Jugoslavia, and Austria. European production in general is inadequate for domestic needs, and the deficit has to be supplied by imports. The largest part of the refined oil products entering international trade is sent to Europe, as the most important region of world consumption outside the United States. In 1928 the European crude oil supply was supplemented by the importation of about 17 million barrels of crude oil from outside sources, about 12 million coming from Persia, and the other 5 million, from the American Zone. Of the total imports, about 14 million barrels were taken by the United Kingdom, which is the only important European refining country that is not a producer of crude oil. The only European country that uses crude oil direct for fuel to any considerable extent is Russia, which used about 17 million barrels in this way in 1928. With the rapid expansion of refining facilities in that country, this use will probably decline. About one half of the net products of oil refining in Europe consists of gas and fuel oil.

Russian Oil Expansion

The most significant factor in the European oil market is the increasing production of Russia. Production from 1910 to 1917 inclusive was maintained at the rate of about 65 million barrels of crude oil per year. In the four years from 1918 to 1921 the average was only 29 million barrels. Since 1921 production has steadily increased to 88 million barrels in 1928 and approximately 103 million in 1929, with indication of further rapid expansion.

Total oil exports in 1913 were about 7 million barrels, including 1 million gasoline, 4 million kerosene, 1.5 million lubricants, and 0.5 million fuel oil. In 1923 only 2.5 million barrels were exported. A rapid increase in exports then began, coincident with increasing production, until by 1928 the total had reached 22 million barrels, made up of 6.5 million gasoline, 5 million kerosene, 7 million gas and fuel oil, 2 million lubricants, and 1 million crude oil. In 1929 exports approximated 29 million barrels. This development has been carried out under centralized government control, with the policy of increasing production for world markets in order to secure greater profits from the export trade. Production is concentrated in the best fields. Pipe lines have been constructed from the two principal fields to deep water harbors on the Black Sea, from which direct bulk shipments may be made to European markets. Some of the largest and best equipped modern refineries have been built at these ports, and others are planned at strategic interior market points. Tube stills and cracking equipment, to secure larger gasoline yields, have been installed. The yield of gasoline from crude oil refined has been increased from about 5 per cent in 1924 to over 11 per cent in 1928. Modern oil storage tanks have been installed in place of the old open air storage, in which most of the gasoline content was lost by evaporation. Natural gas, formerly allowed to escape, is now utilized to an increasing extent in the oil fields. Field operations have been largely electrified with power developed in central stations. Several million barrels of oil, annually lost or inefficiently used, have been saved by these improvements. Thus, in the last four years the oil industry of Russia has been rehabilitated and modernized.

The most significant fact is that much of the improvement has recently been completed or is still under way, and its full results will be shown only in the production and export figures for 1929 and 1930.

Russian oil is supplying the Mediterranean markets, particularly in Italy, where the demand for oil products is rapidly increasing. Large amounts also enter the north European markets. In 1928, 9 million barrels—4.5 million gasoline, 1.5 million kerosene, 1 million lubricants, and 2 million fuel oil—were exported to England, France, and Germany. This influx of Russian oil has retarded the full utilization of the recently constructed British refining capacity.

The increasing export of Russian fuel oil is thus furnishing new supplies for European markets. Furthermore, Russian gasoline may enter the European markets in larger quantities and fill part of the increasing demand. This may retard the increase of our own gasoline exports, and may check the tendency to convert fuel oil into gasoline by new refining processes and postpone any decline in our fuel oil supply.

The Russian program calls for a crude oil output in 1933 about double the 1928 production. Even if a much smaller output is actually secured, Russian competition will undoubtedly be a serious factor in export oil markets, in which a condition of general overproduction already exists.

(c) Increased Crude Oil Output in 1929

The year 1929 was marked by an increase of 160 million barrels in world crude oil production, which resulted in a considerable surplus over consumption requirements. This situation has stimulated discussion of world control of production in the interest of conservation. Temporary overproduction has occurred in the past, but probably never in conjunction with such favorable indications of world-wide potential increases in supply. The United States still retains its dominant position in production and consumption, but many other areas are increasing in importance and appear to have great potentialities of further increase. Since gasoline and fuel oils represent almost eighty-five per cent of

the total of all marketed oil products, they constitute the real index of demand.

Gasoline is the major product for which the demand is rapidly increasing. Its market is determined primarily by extension of the use of motor vehicles. While the United States has by no means reached the saturation point in their use, it can hardly be expected that growth can continue at the phenomenal rate of the past decade. Outside the United States there is apparently a great field for motor vehicle expansion, but it must be recognized that smaller average buying power, lower standards of living, and in some areas poor roads are retarding factors, which indicate that the expansion will be comparatively slow, though steady. Development of new oil production and improved refinery operations abroad will supply a part of the increasing gasoline requirements.

Notwithstanding lower prices the market for fuel oil has not shown signs of great expansion in the past few years in the United States. In foreign markets prices are generally much higher, and fuel oil has already filled the demands for which it is best adapted. Fuel oil has not been able to find a large market in the inland industrial areas lying close to the great coal fields where the greatest energy consumption takes place. Much of its use has been restricted to outlying regions whose total energy requirements are comparatively small and slow growing.

Under these conditions probably one half of the increase of 160 million barrels in world crude oil output in 1929 would have met the increase in actual demand, as is indicated by a total increase of 68 million barrels in storage of crude and refined oils in the United States. The increase of production in the United States, which amounted to 106 million barrels, represented about two thirds of the total increase of the world output, but this was not disproportionately large, as compared with the relative volume of production in this country. The large accumulation of stocks indicated, however, that neither domestic demand nor exports kept pace with increased output. Crude oil imports remained about the same, and an increase of 18 million barrels of refined imports more than balanced the increase of 8 million barrels in oil exports.

Outside the United States the largest increase in output was 31 million barrels in Venezuela. The expansion of the refining of Venezuelan oil in the Netherlands West Indies is furnishing an increased supply of refined products for foreign markets, and this supply is entering some of the markets, particularly for fuel oil, which the United States secured after the decline in Mexican production began. No great changes in production occurred in other American countries. Mexican production continued to decline, and only small increases occurred in Peru and Trinidad.

In Europe the output of Russia increased by about 15 million barrels, and Russian exports of refined oil increased by 7 million barrels. The Rumanian output increased by 4 million barrels, adding to the supply of oil for European markets. Production increased by 5 million barrels in Asia, 6 million in the Netherlands East Indies, and decreased by 1 million in Persia. The developments in Iraq will furnish an additional output when transportation to outside markets is established.

Increased foreign production, combined with improved refining facilities, is thus bringing about increasing competition with products from the United States in all important foreign markets. An overproduction year, such as 1929, has the effect of retarding relative increase of gasoline production from crude oil and making available an increased supply of fuel oil at lower prices.

(d) Present Distribution and Final Consumption of Crude Oil

With the increasing tendency to refine all crude oils, the final distribution of crude oil gives a fair index of the localization of the refining industry and the points at which refinery products, including gasoline, gas oil, and fuel oil, will be available for sale. The most significant features of the present distribution of crude oil will be indicated by a review of the international movements and the internal shipments between different regions in the United States. In this discussion only the final regional distribution of gross production will be considered. Changes in storage and estimated

losses for each region will be dealt with later when the final products of crude oil are considered.

International Movements

A review of the international movements of crude oil in 1928 indicates a total movement of about 185 million barrels. This movement is primarily by tank steamer, except for the export of 10 million barrels across the northern border of the United States to Canada by pipe line or tank car. Considered from a regional standpoint the movement is principally a distribution between American countries. Out of total exports of 162 million barrels of crude oil from American countries, only about 5 million went to Europe and 2 million to Japan, the remainder going to other countries of the American zone.

The United States import of 80 million barrels of crude oil, mainly from Venezuela, Mexico, and Colombia, was the most important movement. Of the total, 71 million barrels were received at Atlantic coast ports, and 9 million, at Gulf ports. Before the decline of large imports of heavy Mexican crude oil, a great deal of crude oil was used direct for fuel in these areas, but at present the crude oil imports are for the most part refined for the domestic market or for export. The result is a large output of gas and fuel oils, which has maintained the total supply of fuel oils available. The Atlantic Coast region is a great assembly point for both domestic and imported crude oil for refining, and the resultant output of fuel oils has made this section one of the great fuel oil-consuming regions of the world.

The second movement in importance was the net import of about 49 million barrels of crude oil by the Netherlands West Indies from Venezuela. A large amount of crude oil is sent to these islands for reshipment to other points, but this has been allocated to the final imports by other countries, so that the figure used here is only the net crude oil that remains for treatment or storage. The Netherlands West Indies, which lie off the coast of Venezuela, represent the best available ports for the world distribution of Venezuelan oil, and consequently large refineries have been located on the islands of Curaçao and Aruba. Venezuelan oil is pro-

duced in areas tributary to Lake Maracaibo, which is too shallow for navigation by ocean vessels. Oil is brought to lake ports by pipe line and then moved by small lake tankers to Curaçao and Aruba. The rapid increase in refining is making larger supplies of fuel oil available for ships, for ships' bunkers, and for export to American and European markets. The political control of the islands by the Netherlands is an added reason for refinery development, as some of the largest operating companies in Venezuela represent British-Dutch interests.

The third large movement of crude oil in the American zone was the import of approximately 24 million barrels by Canada, of which 15 million come from the United States, 6 million from Colombia, and 2 million from Peru. Canadian production of crude oil is less than 1 million barrels, and total consumption of all oil products is now approximately 32 million barrels. Three quarters of the requirements are supplied by domestic refineries, but mainly by the use of imported crude oil. Interior refineries secure their supply from the United States. Refineries in Nova Scotia and British Columbia secure their crude oil largely from other countries. The import of crude oil continues to increase with the expansion of refining facilities. The gas oil and fuel oil produced supply the larger part of the Canadian demand.[1]

The total crude oil export from non-American countries was only 23 million barrels in 1928. The export from European producing countries consisted of only 1 million barrels from Russia. Rumania and Poland export practically no crude oil. The inter-European movement is largely the result of the location of refineries built before the changes in European boundaries resulting from the War, and the refineries are mostly small and relatively unimportant from the standpoint of fuel oil distribution. The export from Asiatic producing countries was 22 million barrels. Persia exported 13 million barrels, 12 million of which went to the United Kingdom and the remainder to Suez and Australia.

[1] Other American movements of crude oil are comparatively small. Cuba imports less than 1 million barrels from the United States to supply a local refining industry. Argentina imports over 2 million barrels, mainly from Peru, to meet the demand of refining industry, which has been expanding faster than the local production of crude oil.

This movement into the United Kingdom represents the most important world movement of crude oil outside of the American zone, and the effort of that country to establish a refining industry to meet part of its large and growing oil requirements. The Anglo-Persian oil company is the only producer of Persian oil, as well as the most important factor in the development of the British refining industry. The expansion of the British industry has been somewhat retarded by the increasing competition of Russian oil products, and total imports of crude oil by the United Kingdom decreased from 19 million barrels in 1927 to 15 million barrels in 1928, of which 12 million were supplied by Persia, as just stated, and 3 million by American countries.

Other crude oil exports from Asiatic countries total only about 9 million barrels from the Netherlands East Indies and British Borneo. Of this total, about 2 million barrels go to Australia, and the same amount to Japan, which are making efforts to expand their refining industries; about 2 million barrels of crude oil for fuel go to British Malaya, and 1 million, to China. In northeast Netherlands Borneo, about 9 million barrels of heavy crude oil from the Tarakan fields are sold for fuel after a settling and cleaning process. It is used largely for bunkering ships, and its export movement is the chief factor in the above figures.

This review of the international movement of crude oil indicates only four major movements, namely, the import of 80 million barrels from other American countries into the United States, 49 million barrels of Venezuelan oil into the Netherlands West Indies, 24 million barrels from American countries into Canada, and 15 million barrels from Persia and American countries into the United Kingdom. The four movements account for 168 million barrels out of a total world export of 185 million.

United States—Internal Redistribution of Crude Oil

The internal redistribution of crude oil in the United States, from the producing regions to the final points of refining, determines the points at which gas and fuel oils become available for consumption or further shipment. In 1928, with a total production of 902 million barrels of crude

oil, the final net amount available for consumption, after deducting exports of 19 million barrels, was 883 million barrels. Actual consumption, after allowing for an increase in all domestic crude stocks of 11 million barrels, exclusive of California heavy crude and fuel oil, was 872 million barrels. Of this amount 836 million were refined, and the remaining 36 million barrels are estimated as representing 18 million barrels used direct for fuel without refining and 18 million barrels lost in storage and in transportation. The final regional distribution of the 883 million barrels available after deducting exports will now be considered.

The principal movement of crude oil, amounting to 335 to 340 million barrels, was from the mid-continent fields—Oklahoma, Kansas, Arkansas, northern Louisiana, and central and northern Texas—to other refining centers. Of an estimated total movement of 336 million barrels from this region in 1928, 231 million barrels moved by pipe line toward Gulf ports, of which 138 million remained in the Gulf Coast region for refining and 93 million were forwarded by tank steamer to Atlantic coast refineries. The remaining 105 million barrels moved by pipe line to north central refineries, Appalachian refineries, and Atlantic coast refineries. In the first two areas mentioned some foreign export occurs, and some shipments of local oil are made by pipe line to the Atlantic coast. A small movement of 3 million barrels took place from California via the Panama Canal to Atlantic coast ports.

As a result of all these movements, the final estimated distribution of the total domestic supply of crude oil available, after deducting exports, was as follows:

Atlantic Coast region	104 million barrels
Appalachian region	33 " "
North Central region	99 " "
Mid-Continent region	217 " "
Gulf Coast region	182 " "
Rocky Mountain region	25 " "
California	224 " "
Total	884 million barrels

From the standpoint of redistribution the most significant results were the assembly of 103 million barrels from other regions at Atlantic coast points, the addition of 138

million barrels at Gulf coast refineries, and an increased supply of 95 million barrels at refineries located in the North Central region. This large movement of interior crude oils to seaboard refining locations resulted in a local supply of refined products available for consumption, for further distribution by water to other coastal regions of the United States, or for foreign export. Large supplies of fuel oil were made available in areas distant from the interior coal fields and at points where a large market for ships' bunkers is found. These factors account for the extensive fuel oil consumption in the coastal regions of the United States.

(e) Development of New Refining Centers[1]

From an international viewpoint the actual progress made in the development of new refining centers is relatively small, but the attention that is being given to such development is significant. The growing consumption of gasoline and the increasing per cent of that product which can be obtained from a barrel of crude oil are making it more practicable to establish refineries in other consumption regions. A greater variety of products had to be produced and marketed under older refining practice. When kerosene was the major product, it was widely distributed to the less advanced countries, which had no need for lubricants and other petroleum products. The large demand for gasoline, however, is characteristic of the more advanced countries, which also demand lubricants, gas oil, and asphalt. With the decline in the per cent of kerosene produced and a possible falling-off in the fuel oil output, the remaining products might all be largely absorbed by a number of important consuming centers that now import all or most of their petroleum products.

The figures showing the final distribution of world crude oil indicate significant changes in the location of refining centers, outside the United States. This development is

[1] The data on refining in foreign countries have been compiled from the following publications of the U. S. Bureau of Foreign and Domestic Commerce: "International Trade in Petroleum Products," Trade Promotion Series, no. 80, 1929; "Petroleum Refining in Foreign Countries, 1929," Trade Information Bulletin, no. 623; and "Monthly Foreign Petroleum Statistics."

most marked in three regions; the Netherlands West Indies, Canada, and the United Kingdom. Crude oil movements to other areas are still small, but the developments in Argentina, France, Spain, Germany, Japan, and Australia are significant. The following table shows our exports to these countries in 1928:

UNITED STATES EXPORTS OF OIL PRODUCTS

Millions of barrels of 42 U. S. gallons

Country	Gasoline	Kerosene	Gas and Fuel Oil	Lubricating Oil
Canada	4.4	0.2	2.4	0.5
Argentina	1.8	0.2	2.1	0.2
United Kingdom	15.6	2.9	4.4	1.9
France	7.7	1.7	0.6	1.4
Germany	1.3	0.8	1.8	1.3
Spain	1.0	0.1	0.2	0.1
Australia	2.8	1.0	0	0.3
Japan	0.7	2.4	5.1	0.2
Total	35.3	9.3	16.6	5.9
U. S. total foreign export to all countries	51.8	21.9	41.6	10.8

Netherlands West Indies

The expansion in the refining of Venezuelan crude oil at Curaçao and Aruba may be considered as thus far offsetting the decline in refinery operations in Mexico, rather than as representing an actual increase in world refining capacity. However, this expansion is having an important effect on the export trade of the United States, since the exports of our refinery products to many markets increased as Mexican exports declined. Now, with the recent expansion of the Netherlands West Indies, products from that region are entering the same markets at the expense of the increased trade that we had thus secured.

The first refinery was built in 1917 by Royal Dutch interests in Curaçao, but did not begin extensive operations until 1920. In 1929 it had a capacity of 175,000 barrels a day. The Lago Oil and Transport Company established a refinery in Aruba in 1928, began exporting in 1929, and now has a capacity of 100,000 barrels a day. Other smaller opera-

tions make up a total refinery capacity, in both islands, of over 300,000 barrels a day.

The export of refined products, exclusive of gas fuel and oil supplied to the bunker trade, increased from 5 million barrels in 1925, to 13 million in 1926, to 21 million in 1927, to 36 million in 1928, and to 68 million in 1929. In 1929 the refined products exported were: gasoline, 10 million barrels; gas oil and fuel oil, 57 million; and other products, 1 million. Thus far the development has evidently been in the nature of a topping process, but extensive "cracking" equipment has been installed, and a much larger export of refined products, outside of gas oil and fuel oil, may be expected to follow.

The significance of this expansion in refining has been to develop a new center of refining whose products are competing in South American and European markets, as well as the coastal regions of the United States; it has thus far affected chiefly the gas oil and fuel oil situation, resulting in an increase in United States imports from 7 million to 20 million barrels and a decline of 6 million barrels in fuel oil exports.

Canada

Canadian refining capacity has steadily expanded from the treatment of 9 million barrels of crude oil in 1919 to about 24 million barrels in 1928. It represents primarily the development of refining at convenient points across the northern border or at seaboard locations in Nova Scotia and British Columbia. In 1928 refinery output consisted of about 10 million barrels of gasoline, 10 million of gas and fuel oil, and 4 million of other products. Total refinery products now represent about three quarters of the total consumption of oil products, which is about 32 million barrels. The industry is based on the importation of foreign crude oil, as domestic production is less than 1 million barrels. In 1928 15 million barrels of crude oil came from the United States, and about 9 million from other American countries.

Increased refining has resulted in a decrease in imports of fuel oil, since the local supply of fuel oil has increased, even though "cracking" for increased gasoline output is well developed.

United Kingdom

The United Kingdom increased its refining of crude petroleum from a negligible amount in 1920 to 19 million barrels of imported crude oil in 1927, which declined to 14 million barrels in 1928. In addition, there is some "cracking" of fuel and semi-refined oils, as well as treatment of the local output of shale oil. The crude oil used comes largely from Persia, and the most important refining operations are carried on by the Anglo-Persian oil company, which controls about two thirds of the total refining capacity of approximately 30 million barrels a year.

In 1928 the refineries treated about 20 million barrels of various oils, of which about 14 million were crude oil, 1 million shale oil, and 5 million other oils. The resulting products were 5.5 million barrels of gasoline and light oil, 2.5 million of kerosene, 9 million of gas oil and fuel oil, and 2 million of other products. The expansion of the local refining industry has been retarded by the competition of foreign oils, particularly from Russia.

The United Kingdom is the greatest consumer of refined oil products next to the United States, with a demand now approximating 60 million barrels a year. Refined output meets about one third of the total demand. The expansion of the refining industry, based on imported crude oil, is significant of a trend toward the shift in refining to new centers in great consuming regions and, if carried out to a greater extent, will result in material changes in the international trade in refined products.

Developments in Other Countries

Argentina is the largest oil consumer in South America, with a total consumption of about 20 million barrels. In addition to refining its own crude oil production of about 9 million barrels a year, this country has shown a tendency to expand its refining industry by importing crude oil, largely from Peru. In 1928 crude oil imports were a little over 2 million barrels. The refining capacity in 1928 was about 30,000 barrels a day, but, with the completion of new refineries including "cracking" equipment, it has now increased to about 50,000 barrels a day. Improved "cracking"

equipment has been installed and will result in an increased domestic output of refined products, through the treatment of domestic and imported fuel oils.

France, with a total consumption of about 20 million barrels of imported refined oil products in 1928, has shown evidence of a definite policy to develop a refining industry based on the importation of crude oil. Regulations have been put in force to license and control all oil imports. Plans have been made for the establishment of refineries at seaboard points, and French interests control a share of the new oil production being developed in Iraq.

Spain's total consumption of oil products is about 3 million barrels a year, with an import of only about 200,000 barrels of crude oil per year. Early in 1928 a government monopoly for the importation and sale of petroleum products was established. The construction of local refineries has been considered, but has not yet been carried out.

Germany consumed about 16 million barrels of petroleum products in 1928. The production of motor fuel from benzine and synthetic oils raises the total consumption to about 20 million barrels per year. Crude oil production is only about 1 million barrels per year, and the remaining petroleum products must be imported. Extensive exploration of the oil-bearing regions is being considered, and this may result in increased crude oil production. Germany's refining industry treats a considerable amount of crude gasoline and kerosene. The chief efforts thus far have been expended on the development of substitute motor fuels.

Japan's total consumption of petroleum products in 1928 may be estimated at about 15 million barrels, when imports of fuel for naval and foreign bunker uses are included. Domestic production of crude oil is about 2 million barrels and is supplemented by the importation of about 1 million barrels from the Japanese concession in Sakhalin, over 2 million barrels from the United States, and 2 million barrels from British and Dutch Borneo. Probably about 4 million barrels of crude oil are handled by its refineries, and a tendency is evident to increase refinery and "cracking" operations. The remainder of the crude oil imported is used direct for fuel.

Australia consumes about 10 million barrels of petroleum products a year. About 2 million barrels of crude oil were imported in 1928, and consideration is being given to the improvement and extension of refining facilities.

While many of the developments that have been outlined are comparatively limited in scope, the general trend in many of the most important consuming markets seems to be toward the development of local refining industries. If carried out, this development would result in material changes in the imports of gasoline and in the points at which gas and fuel oils are produced for market. In the major oil-producing countries there has been a steady increase in refinery capacity, in order to handle the increased output of crude oil, and these countries still represent the greatest concentration of the world refining industry.

3. WORLD CONSUMPTION OF THE PRODUCTS OF CRUDE OIL

The world production of crude oil in 1928 is estimated at 1,328 million barrels of 42 U. S. gallons. After deducting an estimate of the crude oil that was put in storage and not consumed and of the evaporation and other losses that occur in producing, transporting, and refining crude oils, the total net oil products for final consumption are roughly estimated at 1,212 million barrels. The final products resulting are shown in the table on page 52.

Over forty-nine per cent of the total net products were used as fuel oils. The figures include crude oil used for fuel purposes without undergoing refining and the residual refinery gas oils and fuel oils, representing the liquid oils remaining after the extraction of gasoline and kerosene and after the production of such quantities of lubricants, asphalt, wax, and other products as the markets required.

The 600 million barrels of fuel oil consumed are used mainly as a substitute for coal, in the production of heat and power in the oil industry itself and in various manufacturing plants, as fuel for naval and merchant marine vessels, for railroad locomotives, and for heating buildings. The lighter gas oils and distillates are used in the manufacture and enrichment of gas, to an increasing extent for internal combus-

FINAL PRODUCTS OF THE WORLD CRUDE OIL INDUSTRY, 1928

Figures marked with a star represent final net products for consumption

Gross production of crude oil	1,328 million U. S. barrels
Estimated 2 per cent losses	27
Estimated increase in storage	25
Remainder—crude oil consumed	1,276
(1) Crude oil sent to refineries	1,226
(2) Crude oil used direct for fuel	50*
Total crude oil	1,276
(1) Product of refineries	
Gasoline	410*
Kerosene	105*
Lubricants	45*
Gas and fuel oils	550*
Asphalt and road oils	28*
Wax, coke, etc.	24*
Unaccounted for and losses	64
Total sent to refineries	1,226

Final net products of crude oil	Million barrels	Per Cent
Fuel oils—crude direct and gas and fuel oils	600	49
Gasoline	410	34
Kerosene	105	9
All other	97	8
Total	1,212	100

tion engines of the Diesel type, and for the heating of buildings. Using the rough ratio of 3.6 barrels of fuel oil as equivalent in heating value to a short ton of good bituminous coal, the total quantity of fuel oils consumed may be regarded as equivalent to approximately 167 million short tons of coal, or about 12 per cent of the total world coal production. Improvements in refining now make it possible to turn much of the fuel oil into gasoline, but the world output of crude oil has increased so rapidly that the supply of fuel oils has been increasing rather than declining.

The amount of crude oil used for fuel without being refined is comparatively small and will probably decline rapidly in the next few years. Several years ago, at the peak of production of heavy crude oils in Mexico, the quantity of crude oil used direct was much greater. The progress in refining heavy oils, containing less than 5 per cent of gasoline as produced under the old "straight-run" refining

methods, now makes it possible to "crack" these oils and produce large quantities of gasoline. The areas in which heavy crude oil was used direct in 1928 were the Texas and California fields of the United States, using 20 million barrels; Mexico, 5 million barrels; Russia, 17 million barrels; and Dutch Borneo, 9 million barrels. The present amount of crude oil used direct as fuel represents either oil consumed in the production and transportation of oil from fields located at a distance from refining centers or oil in regions where the demand for gasoline is limited and where inadequate "cracking" facilities are available.

Gasoline and kerosene enter into active competition with other forms of energy, even though they have, to a certain extent, created new fields of consumption. Gasoline is predominantly used as a motor fuel for the automobile, the bus, and the truck. Part of this use may be regarded as a luxury consumption, but in the main it has been a development of new passenger and freight transportation. It has retarded the development of steam and electric railroads and in many cases has actually caused a decline in their field of operations. In this field it has been a formidable competitor of coal and electricity, particularly in absorbing much of the natural increase in service required.

In a final analysis, over 90 per cent of the world's oil products are competing directly or indirectly with coal and water power, and the extent of this competition should not be underestimated as a contributing factor in the stationary production of coal from 1913 to 1928.

4. WORLD FUEL OIL DISTRIBUTION AND MARKETS

This section discusses the factors determining the world distribution of fuel oil and the relative importance of the present world consumption of fuel oil in the following regional markets:

The United States and Canada	63 per cent
The Americas—South of the United States	12 "
Europe—including the Mediterranean region	18 "
South and East Asia and Australia	7 "
Total	100 per cent

The United States consumes approximately 60 per cent of the world total. Canada's consumption is only about 2 per cent. In the American countries south of the United States coal resources are lacking, and oil has become the most important source of fuel. In Europe over one half of the consumption is in the oil-producing countries of Russia and Rumania. In the Asiatic and Australian regions the consumption of fuel oil is distributed over wide areas and primarily represents use as a marine fuel and in the production and refining of oil.

(a) Factors Determining the World Distribution of Fuel Oil

Various factors have tended to restrict the world consumption of fuel oils to definite areas. These factors must be duly considered in any attempt to analyze regional consumption; they are a composite of the relation of the ultimate point at which fuel oil is available for sale to the means and cost of moving it to the point of final consumption. The determining factor is the delivered price in competition with other available sources of energy.

It is obvious that the cheapest supply of fuel oil is found at the point of production, either the oil field, in cases where crude oil is used direct for fuel, or the refinery. The latter is by far the more significant, since the greater part of the present supply of fuel oils comes from the refinery. Usually an export movement of fuel oil occurs only after local market needs have been filled. Local shipments are by tank car; long-distance shipments, by tank steamer. Tank transportation is relatively expensive and usually is employed only for shipment to local markets or to regions distant from coal supplies. The movement of fuel oil toward coal-producing areas is limited by increasing freight rates and decreasing coal prices as it nears the coal-producing areas. The purchase of fuel oil by railroads for their own use widens the area of distribution by tank car when the movement of this oil takes place over their own lines.

The cheapness of tank steamer shipment has made this the principal long-distance means of moving fuel oil to

market. Even this cheaper means of transportation generally adds from fifty cents to one dollar per barrel to the local price of fuel oil in the more distant markets. Hence, fuel oil has been available at the lowest prices for railroads and for industries near oil fields and for ships taking bunker oil in ports adjacent to oil-refining areas. The significance of this factor is indicated by a comparison of the prices of bunker oil in the world's chief ports. In general, the price of bunker oil in the United States, Panama Canal, and Caribbean ports is only about one half that in European, Australian, Japanese, and Chinese ports. With the longer steaming radius possible with oil and with the ability to store it in the ship's double bottom, a large bunker business has developed in these ports, and ships entering them bunker for the round trip to other regions so far as possible. This is one of the factors explaining why two thirds of the fuel oil for ships' bunkers is supplied in the ports of the United States, the Caribbean area, and the East Indies, which are adjacent to oil-producing or refining centers.

The larger part of the world's fuel oil consumption is thus either in areas close to oil production, in refining centers, or in coastal regions to which fuel oil can be most readily and cheaply shipped by tanker or where local coal supplies are distant from tidewater. Fuel oil, with few exceptions, has had to find a market in keen competition with coal. Hence the location of markets and the cost of transportation have been important deciding factors in extending the range of its consumption. As a rule it has been unable to move to interior fuel markets close to coal-producing areas, but has been able to secure markets in outlying coastal areas where imported coal is the only other alternative. With its smaller bulk and weight in relation to fuel value and its greater ease of mechanical handling, it has had an advantage over coal.

The peculiar advantages of oil as a fuel for ships have ed to its wide-spread use for this purpose. The need for oil bunker stations at both ends of some of the long trade routes explains the use of fuel oil in the ports of northwestern Europe in close priximity to the coal areas of that region. This use, however, is confined to coastal regions and is com-

paratively limited. Much of the outlying consumption in Asia is attributable to similar conditions. In Japan, China, Australia, and New Zealand a limited fuel oil consumption has developed in regions where coal is available close to tidewater, but largely for bunker use on the long trade routes where cheap fuel oil is obtainable at the other end.

The principal fuel oil-consuming regions, the North Atlantic, the South Central, and the Pacific Coast regions of the United States, the Caribbean region, and the Mediterranean-Russian zone, are all near oil-producing or oil-refining centers or are coastal areas more or less remote from coal-producing regions. In most cases both factors are found. Internal consumption, by railroads and manufacturing industries, is largely restricted to areas adjacent to the oil fields or to refining centers in the United States, Russia, and Rumania.

(b) Regional Analysis of World Fuel Oil Markets[1]

United States and Canada[2]

Consumption of fuel oils, 1928: United States, 358 million barrels; Canada, 14 million barrels; total, 372 million barrels

The United States is the chief producer, as well as consumer, of oil. In 1928 the crude oil production of the United States was about 900 million barrels. In addition, 80 million barrels of crude oil and 12 million barrels of refined products were imported. Exports of all oil products were 155 million barrels. About 837 million barrels of oil remained in the country, part of which represented losses and increased storage. Final consumption of all oil products represented over 60 per cent of the world total.

A much keener competition among the major sources of energy—coal, oil, natural gas, and water power—has developed in the United States than in any other region of the world. Here 39 per cent of the world coal production meets the competition of 60 per cent of the world's fuel oil, 96 per

[1] See Appendix, p. 156, for tables of world fuel oil consumption.

[2] Data are based on the "National Survey of Fuel Oil Distribution," U. S. Bureau of Mines, 1926, 1927, and 1928; official Canadian figures; foreign trade statistics of the U. S. Bureau of Foreign and Domestic Commerce; and the Trade Information Bulletin, no. 622, "Fuel and Power in Canada," 1929.

cent of the world's natural gas output, and 36 per cent of the developed water power. Outside the United States, fuel oil is consumed most largely in countries with inadequate coal resources, and this consumption is less competitive in character and more of a supplementary nature. In foreign markets, outside of Russia and Rumania, the marine use of fuel oil predominates. The greatest competition of fuel oil with coal is in the export and bunker coal trade of Great Britain.

The uses of fuel oil are much more varied in the United States than in any other country. The large consumption for railroad locomotives, manufacturing industries, and heating of buildings finds no parallel in other countries. This variety of use is due to its abundance and low price. The price of fuel oil in United States ports, near the great coastal refineries, is roughly only about one half the price in the ports of Europe, Asia, and southern South America. Consequently, ships engaged in the foreign trade secure as much of their bunker oil requirements as possible in United States ports and in the shorter trade routes can take on enough oil for the round trip. The abundance and low price of fuel oil have thus caused much more varied use and keener competition with coal than in the other world markets.

Large-scale fuel oil consumption developed earlier in the United States than in any other region except the interior of Russia. It began about 1900 and increased rapidly up to the period 1924 to 1928. The consumption in the latter year shows an increase of about 3 per cent over 1927. Because of its firmly established use, any decrease in supply would cause more difficulty and adjustment than in any other region.

As regards the regional consumption of fuel oil in the United States, the bulk is consumed in areas distant from the great interior coal-producing territories. A large part of the crude oil is piped to refineries located at seaboard, where oil products can be distributed advantageously to domestic and foreign markets. Fuel oil is thus supplied to these refineries at the lowest price, while coal transported to the same points has to bear the cost of long hauls by rail. The largest consumption of fuel oil is therefore found in the coastal regions.

The three regions of largest fuel oil consumption are in the North Atlantic states, the states bordering the Gulf of Mexico, and the Pacific Coast states, particularly in California. The greatest inland consumption takes place in the regions of oil production, especially on the railroad lines which connect the South Central states with California, since a cheap fuel oil supply is available at both ends of their route. Thirty per cent of the total fuel oil consumption is in the Pacific Coast states, where coal supplies are inadequate.

The fuel oil consumption of Canada in 1928 was almost 14 million barrels. Of this amount 10.5 million barrels were produced by Canadian refineries, and 3.5 million barrels were imported for domestic consumption and bunker supply. Crude oil production was approximately 0.5 million barrels, so that practically all of Canada's oil supply was derived from foreign sources. Most of the refineries are located at points near the border and import their crude oil from the United States. Outside of the United States and Russia, Canada is one of the leading consumers of fuel oil.

The establishment of import duties on all oil products, except crude oil and fuel oil imported for bunker use by ships, has been an important factor in the rapid expansion of the domestic refining industry, which has about doubled since 1925. Since 1919 imports of fuel oil have fluctuated between 3 and 4 million barrels, but have shown no tendency to increase, while total consumption has expanded rapidly from about 7 million barrels in 1924 to almost 14 million barrels in 1928. The increasing use of fuel oil is thus due primarily to expanding refinery production, and, except in the maritime provinces of the east and west coasts, the consumption is determined by relation to refinery location and output. In 1928, out of a total of 24 million barrels of crude oil treated in the refineries, the output of gasoline was 10 million barrels, of gas oil and fuel oil 10 million, and of kerosene only 1.5 million, leaving about 2 million barrels of other products. Fuel oil thus represents about 42 per cent of the refinery production. On account of the small demand for kerosene and other products and the rapidly increasing market for gasoline, approximately one third of the gasoline output in 1928 resulted from "cracking" fuel oils.

Total energy consumption in Canada for 1928 was equivalent to about 60 million short tons of bituminous coal. Of this total, domestic and imported coal and coke together represented 35 million tons, in about equal amounts. The coal equivalent of water power was estimated at 17 million tons. Fuel oil represented an equivalent of about 4 million tons; natural gas, 1 million tons; and fire wood, 3 million tons. Fuel oil thus amounted to less than 7 per cent of the total. Gasoline, of which 14 million barrels were consumed, was not included in the above estimates, possibly because the full significance of gasoline as a competitive source of energy is just beginning to be appreciated.

Canada is dependent to a large extent on coal imported from the United States and is therefore making every effort to develop domestic supplies of energy, particularly water power. Developed water power installations have now reached a total of 5.5 million horsepower, and it is estimated that projects involving an additional 2 million horsepower are under way. Total domestic coal production has increased from 11 million short tons in 1909 to 14 million tons in 1919, to 17 million in 1920, and to 18 million in 1928. The almost stationary production and importation of coal in recent years have been due to increased efficiency in coal utilization and increasing competition of oil products and water power. The effect of fuel oil has been most notable in British Columbia, where coal production is practically the same as in 1909. The expansion of oil production in California has resulted not only in loss of a market for export coal there but also in an invasion of the fuel market in British Columbia itself.

The regional distribution of fuel oil in Canada is difficult to determine, but an estimate, based on such scattered data as are available and on the location of refinery capacity, indicates consumption of about 2 million barrels in the eastern maritime provinces, about 7 million barrels in Ontario and Quebec, about 2 million barrels in the central provinces, and about 3 million barrels in British Columbia.

About one half of the total consumption is in what is known as the "fuel-less" zone of Ontario and Quebec, which has no local coal production and imports large amounts of

oil and coal from the United States. The long distance haul to bring coal into this area has made it a region of comparatively high-cost fuel and has consequently encouraged both the consumption of fuel oil and the development of water power. The use of oil for heating buildings has been increasing rapidly there and is probably now the leading use; in 1926 it amounted to almost 1 million barrels, and it has undoubtedly doubled since then. In 1928 over 50 per cent of the total United States export of oil burners went to Canada. The price of fuel for domestic use is high; coke retails for about $12 per short ton, and the larger sizes of anthracite, at about $15 per ton. The petroleum-refining, iron and steel, and pulp and paper industries are the other principal consumers of fuel oil and take about 1 million barrels each a year.

As Nova Scotia is an important coal-producing area, consumption of fuel oil is smaller in the eastern maritime provinces and is mainly for bunkering ships and for use in oil-refining.

In the prairie provinces of Alberta, Saskatchewan, and Manitoba local coal and natural gas are available, and the consumption of fuel oil is largely restricted to the product of local refineries. The use of oil for domestic heating has been increasing in Winnipeg and other cities. The other principal uses are in the railroad shops and in the oil refineries.

British Columbia has long been an important fuel oil market, and the product of the local refineries is supplemented by the importation of about 2 million barrels per year from California. Consumption started soon after the development of large-scale oil production in California, and fuel oil was used by the Canadian Pacific Railway as early as 1911. The railroads are still the largest consumers and use about 2 million barrels per year. The remaining consumption is for bunkering, oil-refining, and other industrial uses. Use for domestic heating is comparatively small, but is increasing.

The consumption of fuel oil in Canada is widely scattered both regionally and by uses. It is largely based on the product of local refineries and has been increasing with the

expansion of the local refining industry. Of the total, approximately 14 million barrels, about 1.5 million barrels are used as fuel by the oil refineries; about 2 million barrels, by railroads; about the same amount, for heating; probably at least 2 million barrels, for bunkering; and the remainder, for industrial purposes, with iron and steel, pulp and paper, mines and smelters, gas manufacture, and food industries as the principal users. The largest consumption is in areas of high-cost coal. Relatively fuel oil is not a large factor in the total energy consumption and could be replaced by coal in case of a decline in the comparatively small import or in the local supply due to the extension of the "cracking" of fuel oil to produce gasoline. The chief effect of a decline in supply would be to stimulate coal imports in Ontario and Quebec, local coal production, and, possibly, railroad electrification in British Columbia.

Americas—South of the United States

Total fuel oil consumption in this region for 1928 is estimated at 71 million barrels, or an equivalent of about 20 million short tons of coal. The total coal production of these countries is about 3 million tons a year, and the coal equivalent of water power developed would be about 3 million tons. In addition, about 7 million tons of coal are imported annually, mainly from Great Britain to Argentina and Brazil. In terms of coal the total energy consumption of the whole area is thus about 33 million tons, of which fuel oil furnishes approximately two thirds.

This comparatively small total energy consumption is due to the lack of fuel-using industries, to the mild climate requiring little heat for domestic purposes, and to the extensive use of charcoal for cooking. Water power is used in the textile industries of Mexico and Brazil and for some large mining enterprises. The bulk of the coal and fuel oil is used for transportation, railroad fuel, and ship bunkers. The oil industry is a large consumer of fuel oil, as extensive oil production and refining are carried on in Mexico, Venezuela, the Netherlands West Indies, Colombia, Trinidad, Peru, and Argentina. The Cuban sugar industry and the nitrate and copper mines of Chile are also large consumers. Fuel

oil has been an important supplementary source of energy in the development of this area, and its use will undoubtedly continue to increase if adequate supplies are available.

In considering the consumption of fuel oil, the area may be subdivided into the following three regions, with their estimated fuel oil consumption in 1928 indicated:

Caribbean region	44 million barrels
West coast of South America	9 " "
Eastern South America	18 " "
Total	71 million barrels

Caribbean Region

Consumption of fuel oil in this area is estimated at about 44 million barrels in 1928, distributed as follows: Mexico 13, Central America 2, Panama Canal 8, Cuba 5, other West Indies 4, Netherlands West Indies and Venezuela 10, and Colombia 2. In 1928 about 11 million barrels of gas and fuel oils were exported to this region from the United States, the remaining 35 million are produced by the countries in the region. Oil has become the dominant fuel in all of these countries because of available supplies over a long period of time, beginning with the production of heavy fuel oils in the Gulf region of the United States and continuing with the enormous output of Mexican oil, which reached a peak about 1923. Since Mexican oil began to decline, new supplies have become available in Venezuela and Colombia.

Total coal consumption is relatively small. About 1 million tons of coal are produced in northern Mexico near the United States border and used locally. Cuba imports about 600,000 tons a year from the United States, and several hundred thousand tons are supplied by the latter for ship bunkers at the Panama Canal. In all, possibly 3 million tons of coal are consumed in the area. A large part of the fuel oil consumption of the region is concerned with the production, refining, and movement of oil.

On account of the decline in the oil industry of Mexico, fuel oil consumption has decreased in that country from around 20 million barrels in 1924 to about 13 million in 1928. The larger part of the decline is due to the decreased amount

used for bunker purposes. Less than 2 million barrels supply the present bunker needs, and about the same amount is used by oil companies in operation and refining. Railroads and industries are large users, of about equal importance.

The Canal Zone is well located to secure supplies of cheap gas and fuel oil for bunker purposes. About 8.5 million barrels were received there in 1928 for that purpose. In 1929 receipts were about 1.5 million barrels less. About 80 per cent of the fuel oil used has been imported from the United States, but recently imports from the Netherlands West Indies have been gaining.

The expansion of oil production in Venezuela and refining in the Netherlands West Indies has brought about an enlarged consumption of fuel oil, which balances the decline in Mexican consumption. Total consumption for the two areas combined is estimated at 10 million barrels, over half of which represents bunker oil used by the fleet of tankers, and the remainder, fuel oil for refining and producing operations.

Cuba is the other chief country of oil consumption in the region. Mexico was the chief source of fuel oil supply for Cuba in 1924, but oil from the United States and the Netherlands West Indies has been filling the demand as the Mexican supply declined. Consumption in 1925 was as high as 8 million barrels, but has since fallen to 5 million. The prosperity of the sugar industry affects the activity of the railroads and other consumers of oil. The effect of the development of fuel oil on coal consumption is indicated by the decline in Cuban coal imports from 1.4 million tons in 1913 to 0.6 million in 1927.

West Coast of South America

This area has been a considerable consumer of fuel oil since the early development of Californian and Peruvian crude oil production. Consumption increased from 3 million barrels in 1913 to 8 million in 1924, fluctuated between 6.5 and 7.5 million from 1925 to 1927, and reached a peak of about 9 million barrels in 1928 and 1929. California has been the major source of supply, although for a time Mexican oil was an important factor. Out of a total consumption of

9 million barrels in 1928, about 7 million came from the United States and 1.5 million from Peru. About 0.5 million barrels of fuel oil from the Netherlands West Indies entered the market in 1929 and may indicate a further increase from that source.

Chile is the principal consumer, using about 7 million barrels a year, while Peruvian consumption is a little over 1.5 million barrels. The nitrate and copper mines in northern Chile are the chief consumers and under present conditions use over 6 million barrels a year. The railroads which serve this mining area use about half a million barrels a year for fuel, and an equal amount is taken by Peruvian railroads. The remainder is consumed by other industries in the coastal regions, the oil-producing and refining industry in Peru being one of the chief users. Very little fuel oil reaches the coal-producing region of central Chile. The market for bunker oil for ships is very small, because a cheaper supply can usually be secured at the Panama Canal or at Caribbean ports, and, in addition, much of the cargo movement is by tramp steamers, which are ordinarily coal- rather than oil-burners.

The increase in fuel oil consumption by the nitrate mines in Chile has replaced an almost equal amount of coal that was brought in as ballast by steamers coming for nitrate cargoes. About 1.6 million short tons of coal were imported by Chile in 1913; less than 0.5 million, in 1920; and only about 100,000, in 1928. The largest coal mines in South America are in central Chile. The output of these mines has remained almost stationary, at about 1.5 million tons since 1913. The coal is of rather low grade and finds a local market for railroad and industrial use. In 1925 an effort was made to stimulate this coal industry and to protect it from the competition of imported coal and oil, by placing a fixed tax on coal imports and a graduated tax on fuel oil imports. As a result, domestic coal has replaced imported coal to some extent, but has made little progress in competing with imported oil in the northern mining region. If the available supply of world fuel oil should decrease, an increase in either domestic or imported coal consumption would take place.

Eastern South America

The total consumption of fuel oil in this area in 1928 was about 18 million barrels. Argentina was the chief consumer, with 14 million barrels, while Uruguay used a little less than 2 million barrels and Brazil, a little more. The use of fuel oil developed much later than on the west coast. Consumption in 1913 was negligible, but by 1920 it had reached 7 million barrels and by 1924, 11 million. In the next five years it almost doubled, and may still further increase. Three factors of importance in the expansion in consumption were the lack of adequate coal resources, the development of crude oil production in Argentina, and the increasing surplus of oil for export from Mexico after 1914.

In 1920 Mexico supplied 6 million, and Argentina, 1 million, out of the total consumption of 7 million barrels. With the decline in Mexican supply, imports from the United States rose rapidly, and the refinery output in Argentina increased. In 1927 the total supply for consumption was 16 million barrels, 7 from the United States, 7 from Argentina, 1 from Mexico, and 1 from the Netherlands West Indies. Since then the source of supply has undergone another change. Imports from the United States dropped to 4 million barrels in 1928 and to 1 million in 1929, while imports from the Netherlands West Indies rose to 4 million barrels in 1928 and almost 9 million in 1929.

In 1913 these countries relied almost entirely on coal imports for their fuel supply, the coal coming mainly from the United Kingdom. The total coal imports in 1913 were about 8 million short tons. The shortage of coal during the War period stimulated increased production and use of oil in Argentina and development of local coal and water power in Brazil. Coal imports in 1920 were less than half the total for 1913. By 1928 they had gradually increased again with the enlarged energy demands due to the economic development taking place in this region. Coal imports in 1928 were 6 million short tons and, with the half million tons of annual production in Brazil, made up a total less than the 1913 consumption. Water power development in Brazil has increased from 250,000 horsepower in 1920 to 640,000 horsepower in 1928.

No very accurate data on the uses of fuel oil in this area have been found. In Argentina the railroads are the principal users, and there is also some consumption for bunker use by merchant and naval ships. Total fuel oil consumption now represents the equivalent of over 5 million short tons of coal. Three quarters of the total is used in Argentina, which has no developed coal of its own and no water power convenient to the chief centers of population. Without the present fuel oil supplies, greatly increased imports of coal would be required.

Europe—Including the Mediterranean Region

The area included in this discussion comprises all of Europe and also the sections of northern Africa and western Asia bordering on the Mediterranean Sea. The total fuel oil consumption of this area in 1928 is estimated at 108 million barrels, or the equivalent of about 30 million short tons of coal. Over one half of this total is for internal consumption in the two chief oil-producing countries of Europe, Russia and Rumania, both of which lack adequate supplies of energy from other sources. Consequently any discussion of the competition of fuel oil with coal production is concerned primarily with fuel oil consumption outside these countries.

Undoubtedly the increasing use of fuel oil has been a factor in the decline in the export of British coal to European markets and in the depression of the British coal-mining industry. It is, however, only one of several factors, and the others are probably of even greater importance. The rearrangement of political boundaries and the resulting change in the control of coal resources have stimulated coal mining on the continent. The French coal mines in the devastated area have been completely rehabilitated and are now producing 7 million short tons more than in the pre-war period. Germany has been making up for the loss of important coal-mining regions by an intensive development of the remaining resources, particularly low-grade brown coals. The coal mines under Polish control are actively seeking an export market. The Netherlands has greatly increased its coal production, as a result of inability to secure imported coal during

the War. The increased efficiency in coal utilization and the depression in the coal industry are both important factors to be considered. In the United Kingdom the depressed condition of the iron and steel industry has retarded any expansion in the domestic market. The extensive development of water power resources in Italy, Spain, France, Switzerland, Norway, and Sweden, which has taken place since the War, has also supplied a considerable part of the increase in total energy demands.

It is obvious that, in a market consuming 705 million short tons of coal in 1928,[1] a consumption of fuel oil, equivalent to 30 million short tons of coal about half of which is in non-competitive territory, can have been only a comparatively small factor. While fuel oil and water power have both competed with coal in Europe, they do not present any such competitive energy situation as is found in the United States. Probably a more disturbing factor has developed in the expansion of gasoline consumption by automobiles, trucks, and busses, which have become formidable competitors of the railroads in the short hauls prevalent in most European countries.

The proportional uses of fuel oil in Europe vary considerably from those in the United States. In the great coal-producing countries of northwestern Europe fuel oil consumption is largely restricted to the seaboard locations. The principal use is for naval and merchant ship bunkers. The largest consumption is found in the United Kingdom and, to a less extent, in continental ports. It has caused a distinct decline in the demand for bunker coal. The use of gas oil in the manufacture of gas is another important form of consumption. The use of fuel oil for industrial, railroad, and heating purposes is comparatively unimportant. Among the Mediterranean countries Italy is the leading consumer. Here again the principal demand is for marine purposes. It is only when we reach the oil-producing countries of Russia and Rumania that large consumption for railroad, industrial, and other purposes is found. Consumption of fuel oil in Russia approximates 45 to 50 million barrels per year, in Rumania, about 8.6 million.

[1] Lignite has been reduced to terms of equivalent bituminous coal.

South and East Asia and Australia

This region includes the important oil-producing countries of Persia, India, the Dutch East Indies, and British Borneo. Japan, including Sakhalin, is a smaller producer, and production is developing in Iraq. Total crude oil production in 1928 was about 90 million barrels. For the region as a whole net production of oil is about balanced by net consumption, but extensive export and import movements occur. The larger part of the Persian oil finds a market in Europe either as crude oil or as refined products. An almost equal amount of oil from the United States, mostly as refined products, is imported, finding its chief markets in Japan, China, Australia, New Zealand, and the Philippines. Practically all of the oil produced in the East Indies is consumed in that region, with shipments extending to India, Australia, and Japan. India, besides consuming its own production, is a large importer from Persia and the East Indies. A small amount of oil is still imported by India from the United States, and recently Russian oil has been entering the market. Production in the region as a whole has been increasing steadily, and competition with imported oils is becoming keener. The imports from the United States represent a market for the surplus production of California. The long established activities of the Standard Oil interests in the Orient and the more recent development of California production by the Dutch-Shell interests are important factors in maintaining this trade.

The consumption of fuel oil in the entire region is estimated at about 40 million barrels in 1928. In proportion to the vast population of the region, fuel consumption is very small. This is due to the backwardness of industrial development and the mild climate of the region. The iron and textile industries rely on coal and water power. Fuel oil finds its major uses as a marine fuel and in the oil industry itself.

Of the total fuel oil consumption, 8 million barrels are imported from the United States, and the remainder is derived from the oil produced in the region. In addition, about 9 million barrels of heavy crude oil from the Tarakan district of Dutch Borneo are used direct for fuel after a slight cleaning treatment.

The location of the Far East, at the end of the long trade routes from Europe and the United States, makes a local supply of bunker fuel for ships particularly important. Strategic coal developments have taken place in Japan, Australia, India, and South Africa. With the development of oil-burning ships a supply of fuel oil became essential. Oil from various sources is available at Suez; Persian oil is available for the ports of western India and Ceylon; and East India oil is adjacent to Singapore. In Australia and New Zealand oil must be brought from the East Indies or the United States. For the important bunkering stations in the Philippines, Japan, and China no adequate local oil is available, and fuel oil must be assembled from the East Indies or California. The larger part of the fuel oil exports of the United States to Asia is sent to the regions just named. In addition, the requirements of the Japanese navy must be met from the same sources. The oil refineries of Japan, dependent partly on crude oil imported from the United States, produce large quantities of light fuel oils for use by the fishing fleet.

The regional consumption of fuel oil may be roughly grouped in four areas:

Japan-China	11 million barrels
East Indies-Philippines-Malaya	10 " "
Australia-New Zealand	3 " "
India-Ceylon-Persia	16 " "
Total	40 million barrels

The Japan-China area has ample coal facilities, and water power is being rapidly developed in Japan. Fuel oil is used primarily as a marine fuel for navy, merchant ships, and fishing fleet. Energy demands are increasing so rapidly, with Japan's expanding industrial development, that the increase in the use of fuel oil, while it has absorbed part of the new demands, has not caused a depression in the coal industry. Japanese oil production has been stationary, at less than 2 million barrels a year, but recent developments in concessions in Russian Sakhalin show an increasing rate of production over the previous output of a little less than 1 million barrels annually. The output is used by the Japanese navy. About 2 million barrels of crude oil and

5 million barrels of fuel oil were imported from the United States. In addition, some crude and fuel oil came from Borneo. Japan's final consumption of all oils is about 14 million barrels, of which two thirds is Diesel and fuel oil. China consumes a total of 9 million barrels of oil, two thirds of which is kerosene. Less than 2 million barrels of fuel oil is used for bunker purposes.

The Dutch East Indies and British Borneo produced about 37 million barrels of crude oil in 1928, over half of which was ultimately used as fuel oil. A considerable amount of oil is used as fuel by the oil industry itself, and the larger part of the remaining fuel oil is used for marine purposes at distributing stations in the islands, at Singapore, and in the Philippines, Australia, and India. The Royal-Dutch interests dominate production and distribution. The steady expansion in oil supply in this area has practically monopolized adjacent markets for oil products. Oil is the most important source of energy in this area, as local coal production is only a little over 2 million tons.

Australia and New Zealand both have coal deposits near tidewater, with a total annual production of around 17 million tons. The chief centers of population in Australia are in the Southeast, a long distance from the East Indian oil fields. Consumption of fuel oil, consequently, has been restricted by the long and expensive haul toward a region of cheap coal production. The consumption of fuel oil in Australia and New Zealand is 3 to 4 million barrels, which represent the equivalent of only about 1 million tons of coal, as compared with a total coal output of fifteen times that amount. Consequently, fuel oil is largely restricted to marine uses, in which it has the greatest advantage in economies of labor and space. Total consumption of all oil products, however, is around 12 million barrels, as this is an important gasoline market with a rapidly increasing use of automobiles.

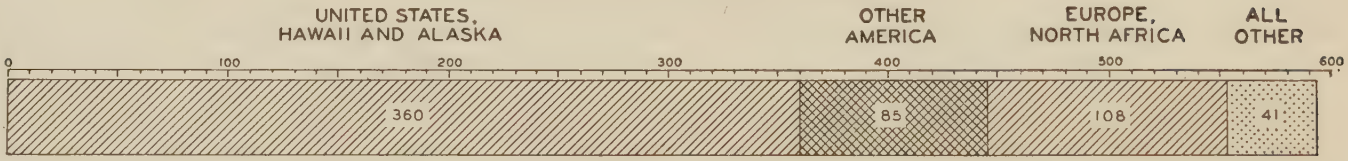
The last area, including India, Ceylon, and Persia, has a crude oil production of 51 million barrels, 8 million in India and 43 million in Persia. India consumes far more oil than the country produces, but Persia has a large surplus, almost 30 million barrels of which is sent to Europe. Oil markets

west of India and on the east coast of Africa are very limited, and Persian oil can not move in large quantity into the market area of the East Indies. India, including Ceylon, is the main oil consumer of this area, with a total estimated consumption of all oil products of almost 20 million barrels. About 7 million barrels of fuel oil are used, and 8 million barrels of kerosene. Gasoline consumption is relatively small. India produces about 24 million tons of coal a year, and this fact explains the comparatively small part played by fuel oil in total energy consumption. Western India is nearest to the Persian oil fields and farthest from the domestic coal regions, and a considerable use of fuel oil for railroad purposes has developed in this area. The remainder of the fuel oil is used for marine purposes and by the oil industry.

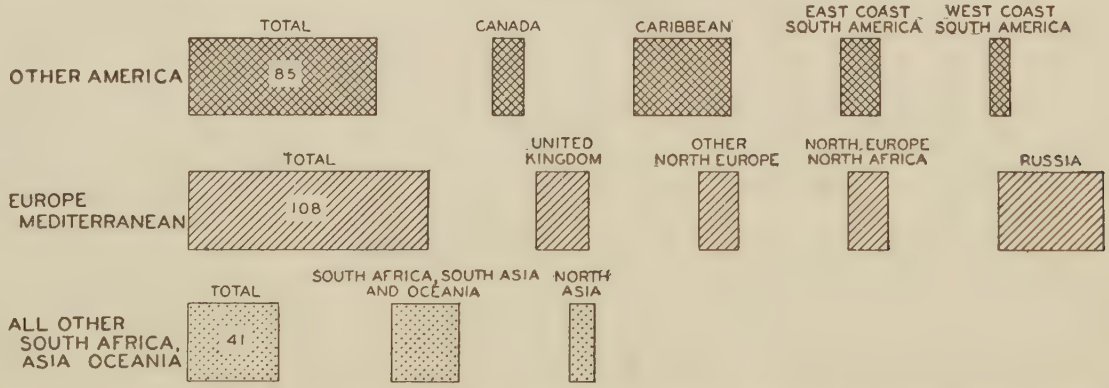
Persian consumption of oil is small, except for oil required in the oil fields and refining industry and for bunkering tankers, which carry the export oil to its markets. The latter amounts to a total of several million barrels. Northern Persia borders on the Caspian Sea and, therefore, secures its oil supply from the Russian fields. The recent development of new oil fields in the neighborhood of Mosul in Iraq promises additional production from the great oil zone extending from Persia to the Russian fields. Because of the inland location of these new fields and the presence of the Persian fields to the South, further development in this area is awaiting the construction of a pipe line through Syria or Palestine to a Mediterranean port from which the oil can be shipped readily to European markets.

World Fuel Oil Consumption by Regions (Including all Bunker Oil), 1928

(All figures in million U. S. barrels of 42 gallons)



DETAILS OF REGIONS OUTSIDE THE UNITED STATES
ON THE SAME SCALE



Detailed figures of world consumption will be found in tables in the appendix, pages 156–158.

PART III

PRODUCTION AND CONSUMPTION OF FUEL OIL IN THE UNITED STATES

SUMMARY

PART III undertakes a detailed discussion of fuel oil consumption in the United States, which represents about 60 per cent of the total world consumption. Section 1 is a historical study of consumption. The significant factors in the increase of consumption from about 11 million barrels in 1899 to almost 360 million barrels in 1928 are indicated. Section 2 discusses the present annual supply of fuel oils available for export and for domestic consumption and the factors affecting the distribution. Section 3 gives a detailed analysis of the export market, both foreign and non-contiguous territorial. The rapid expansion of exports since 1923 has been due to an increased domestic surplus, particularly in California, and to a decline in Mexican exports to foreign markets. The recent expansion of fuel oil supply from Venezuelan oil refined in the Netherlands West Indies is largely responsible for a decline of United States exports in 1929. Sections 4 and 5 present a detailed study of the domestic market for fuel oil by principal uses and by regional consumption, setting forth the varied uses and the wide-spread competition of oil with other sources of energy. A similar large consumption by railroads and manufacturing industries is found only in Russia. The rapidly expanding use of oil for heating buildings is of primary importance only in the United States. Consumption by regions indicates the close relation to oil-producing areas and to coastal regions distant from coal fields. The rapid expansion of fuel oil consumption in the Atlantic Coast region has resulted in keen competition with coal in that area.

1. TREND OF FUEL OIL CONSUMPTION, 1899–1929

(a) Total Consumption and Character of Supply

To determine the total consumption of all fuel oils it is necessary to correlate two sources of supply, namely, crude

oil used direct for fuel and refinery production of gas and fuel oils. The use of crude oil direct for fuel was characteristic of the period when refinery methods could produce little or no gasoline from heavy crude oils. Large quantities of California and Gulf crude oil in the United States, of Mexican heavy crude oil, and of Russian crude oil have been so used in the past. With present "cracking" methods heavy crude oil can be made to yield large quantities of gasoline, and progress in this method of treating crude oil is causing a rapid decline in the use of crude oil direct for fuel. The estimated total amount of oil so used in 1928 was approximately 50 million barrels, of which about 20 million were used in the United States. This figure contrasts with a consumption of from 50 to 100 million barrels of such oils in many past years in the United States.

In the estimated figures for the trend of the consumption of fuel oils, census years have been taken for which figures covering the consumption of fuel oil by manufacturing industries are available. Records of other non-manufacturing uses are available in part. These consumption records have been balanced by the total supply of fuel oils available either as crude oil used direct or as produced by refineries, and a rough estimate of total consumption has thus been arrived at. Since 1926 an annual survey of the consumption of fuel oil has been made by the United States Bureau of Mines, and their figures are used in the detailed discussion by regions and uses.

(b) Historical Growth of Consumption, 1899–1929

Fuel oil consumption on a large scale did not begin until after 1900. Prior to 1926 figures for consumption are obtainable only for census years, and even these figures are only approximate partial estimates, indicating the general trend and the development of the principal consumption uses.

In 1899 the indicated consumption of fuel oils in the United States was about 11 million barrels, of which about 8 million represented refinery product and the remainder, crude oil used direct. The use of light crude oil for refining and the large demand for kerosene resulted in a comparatively small refinery production, which was mostly gas oil. Some heavy

crude oil had been produced for several years in California, and its use as a fuel had passed the experimental stage, about 2 million barrels being used for railroad and industrial purposes. About 5 million barrels of fuel oils were used in the Atlantic Coast area, of which 3 million were in the gas industry; and about 4 million barrels were used in the North Central states, divided about equally among the gas, iron and steel, and oil industries.

In the period 1900 to 1909 there was an extremely rapid expansion in fuel oil consumption from 11 million barrels to approximately 75 million. The fuel oil was secured entirely from domestic sources, imports being negligible. The amount of crude oil refined increased from 52 million barrels to 121 million, and the output of gas and fuel oil rose from 8 million barrels to 41 million. Almost as much more heavy crude oil was used direct for fuel in Texas and California.

In 1909 consumption in the North Atlantic coast states was about 12 million barrels, of which 8 million were in the manufacture of gas. In the North Central states consumption was 8 million barrels, by manufacturing industries. In the South Central and Gulf region consumption was about 22 million barrels, almost half of which was used by the railroads, and the remainder, by the oil industry and other industrial plants. The Pacific Coast area consumed about 34 million barrels, most of which was used in California. About 14 million barrels were used by railroads; several million barrels, by ships; and about 5 million, by gas and electric companies. Oil had been generally adopted as a fuel, and coal consumption and import had rapidly declined.

The greatest consumption zone was from the Gulf region to California, where railroad consumption had expanded to about 23 million barrels with supplies available at both ends of the route. The movement of Texas oil by boat to the Atlantic coast had started, and oil consumption, particularly in gas manufacture, had been stimulated. This period firmly established the consumption of fuel oil; in most uses it had passed the experimental stage and was ready for expansion with further increases in supply.

In the period 1910 to 1919 consumption of fuel oils—gas oil, fuel oil, and crude oil for fuel—increased almost three-

fold, from 75 to 210 million barrels. The amount of crude oil refined rose from about 121 million barrels to 362 million. The production of gas oil and fuel oil by refineries rose from 41 million barrels to 182 million. A large import of heavy Mexican crude oil greatly increased the supply of fuel oils available in the Atlantic coast states, and the total consumption of that area rose from 12 million barrels to 58 million. The Pacific coast consumption increased by 39 million barrels; the Rocky Mountain area, 4 million; the South Central Gulf region, 33 million; and the North Central states, 12 million. The great expansion of crude production in the Mid-Continent area and the development of production in the Rocky Mountain region broadened the area of fuel oil consumption.

By 1919 railroad consumption was almost 40 million barrels; bunker use, including the navy, about 39 million; and use in gas manufacture, 23 million. The shortage of coal during the War was a great stimulus to the expansion of fuel oil consumption.

The period 1919 to 1929 requires only brief comment here, as it is discussed in detail in various parts of this report. Consumption of fuel oil expanded from about 210 million barrels to about 360 million in 1928. The larger part of the increase had been attained by 1924, as a result of the enormous expansion of the crude oil output in California, Texas, and Oklahoma. Consumption showed a more stationary trend from 1925 to 1928. The most notable factor was the rapid increase of consumption for commercial and domestic heating.

2. PRESENT SUPPLY AND CONSUMPTION

In 1928 the total consumption of all fuel oils in the United States approximated 360 million barrels, as determined by a survey of consumption made by the United States Bureau of Mines. The total available supply indicated by production figures is larger than this consumption figure. By checking all statistics of crude oil and by deducting an estimated loss in transportation and storage of two per cent of the total crude oil produced, the amount of crude oil, used direct for

fuel without refining was estimated at approximately 20 million barrels. This estimate includes heavy oils used in California and in the Mid-Continent and Gulf areas and a small amount of imported crude oil used in the Atlantic Coast region. By checking all figures of gas and fuel oil production, stocks, including California heavy crude and fuel oil stocks, imports, and exports, the apparent amount of fuel oils available was computed at 384 million barrels. Apparently this total includes some gas oil and fuel oil re-run for cracking and not sold. According to the best estimates obtainable, the amount of oil included in the total production figures of gas oil and fuel oil that was re-run in 1928 was about 20 million barrels. This would make the total available supply of all fuel oils about 384 million barrels—364 million refinery oils and 20 million crude oil used direct. This figure is about 25 million in excess of that determined by the consumption survey and indicates either that the consumption survey is incomplete or that the amount of losses and fuel oil re-run is greater than estimated. The figures used in the detailed discussion of consumption by uses and regions in this report will be based primarily on the consumption surveys made for 1926, 1927, and 1928 by the United States Bureau of Mines.

3. FOREIGN AND NON-CONTIGUOUS TERRITORIAL EXPORT MARKETS

The export of fuel oil generally represents a surplus above the requirements of the local market. Presumably it must sell at the point of destination for at least the local price plus the cost of handling and transport. The tanker rate from Gulf ports to the North Atlantic ports is about thirty cents per barrel for crude or fuel oil. The cost of shipping fuel oil from California to Oregon and Washington has varied from fifteen to twenty-five cents per barrel during the long period in which that movement has occurred. Large quantities of Mexican oil have been shipped into the United States with a transportation cost of twenty to fifty cents per barrel. On longer hauls the cost will rise proportionately. In consuming countries at the greatest distance from the point of origin of

fuel oil the price will generally be from 50 per cent to 100 per cent higher. Where cheap local coals are available, fuel oil will be imported only in limited quantities and for uses in which it offers the greatest advantages, as is the case with bunker oil. In markets where no nearby coal is available, and all fuel must be imported at a high cost, fuel oil can more readily compete. Since Great Britain has been the greatest world coal exporter, our fuel oil exports have been in competition primarily with British coal and, to a lesser extent, with our own coal exports.

Any decline in the fuel oil supply in the United States would undoubtedly be felt first in a decline in export, for the reasons just outlined, because of the fact that interregional shipments could be made more readily between different parts of the United States than to the more distant markets to which fuel oil exports now go. The purpose of this section is to indicate where those present export markets are and to account for the distribution of our surplus fuel oil, before undertaking an analysis of the remaining fuel oil that is consumed in the United States.

In 1899 only about 0.5 million barrels of gas and fuel oils were exported. Europe was then the chief market, and export to Alaska and Hawaii had not started. In 1909 these exports had increased to about 3 million barrels, mostly to Great Britain. In addition over 2 million barrels of California crude oil for fuel were exported, of which 1.5 million went to Hawaii and Alaska. This expanding export coincided with the rapid increase in fuel oil supply in California and Texas. Heavy California crude fuel and gas oils obtained by topping Texas crude oil were the chief export items.

In 1914 exports of gas and fuel oils had risen to 17 million barrels, and about 2 million barrels of California crude fuel went to Hawaii and Alaska. The market area had begun to broaden, as about 3 million barrels went to Chile; 3 million, to Canada; 1 million, to Panama; and most of the rest, to Europe. Exports increased rapidly during the War period and reached a maximum of about 31 million barrels in 1918, 18 million going to Europe, 8 million, to Canada, 2 million, to Hawaii and Alaska, and about 1 million each, to Mexico, the Canal Zone, and Chile.

Exports dropped to 17 million barrels in 1919, and no significant changes took place until 1923, when a rapid expansion began, as the result of increasing crude oil production, particularly in California. The following table indicates the export trend from 1922 to 1929.

UNITED STATES FUEL OIL EXPORTS TO FOREIGN AND NON-CONTIGUOUS TERRITORIAL MARKETS[1]

In millions of barrels of 42 U. S. gallons

	1922	1923	1924	1925	1926	1927	1928	1929
Europe	7	10	11	9	10	10	10	7
Japan	1	2	3	2	2	4	5	5
Other Asia	2	2	3	3	3	3	3	3
Hawaii	2	4	3	3	3	3	2	2
Canada	3	4	3	4	4	2	2	2
Mexico	1	2	3	1	1	1	1	2
Panama Canal	1	5	4	4	5	7	5	3
Cuba	0	0	0	1	0	2	2	3
Porto Rico	0	0	0	0	0	1	1	1
Other West Indies and Central America	1	1	0	1	1	2	3	2
Chile	1	3	5	5	4	4	6	6
Argentina, Brazil, Uruguay	0	1	1	2	4	7	4	1
All other	0	0	2	1	1	1	1	1
Total	19	34	38	36	38	47	45	38

[1] Including crude oil used for fuel.

The high point in fuel oil exports was reached in 1927, when over 47 million barrels were exported. In 1928 exports dropped to 45 million barrels, and in 1929, to 38 million. The gain in 1926 and 1927 represented an expansion in markets formerly served by Mexican fuel oil. The loss of markets in 1929 was due to the rapid increase in fuel oil supply from the Netherlands West Indies, where crude oil from Venezuela is refined.

The European market took about 10 million barrels of gas oil and bunker fuel, until the drop of 3 million barrels in 1929, due to increasing supplies from other sources and to a stationary demand in north Europe. About one half of the total has gone to the United Kingdom, and most of the rest to other northern European countries. About 10 million barrels go to Asia, of which Japan takes about 5 million for naval and bunker fuel oil. The total of about 3 million

barrels for the rest of Asia is divided among three consumers, the Philippines, China, and New Zealand, with bunker oil as the chief requirement. Hawaiian consumption is from 2 to 3 million barrels, over 1 million being used for bunkers, and the rest, for the sugar and fruit-canning industries, railroads, and public utility plants. Exports to Canada go mainly to British Colombia for railroad and industrial use. Export to Mexico is for consumption in the mining industries of the northern region distant from the oil-producing area of that country. From 7 to 8 million barrels of fuel and Diesel oils are now used for bunkering ships passing through the Panama Canal. Recently Netherlands West Indies oil has been replacing fuel oil from the United States in this trade.

Exports to Cuba, Porto Rico, other West Indies, and Central America also began to expand in 1925 and now total about 6 million barrels. This development also was due to the replacement of Mexican fuel oil by United States exports. Present exports to Chile are about 6 million barrels. Consumption there is primarily in the nitrate and copper mining areas in the northern part of the country and varies with the activity of these industries. Expansion in the import of fuel oil has largely replaced former coal imports. Exports to the countries in southeastern South America increased in 1925, reaching a maximum of 7 million barrels in 1927, and then declining to only 1 million barrels in 1929. The same trend is shown here, namely, decline in Mexican fuel oil, increase of exports from the United States, and entry of Venezuelan oil from the Netherlands West Indies as a competitor.

In 1928 Europe and Asia, including Hawaii, each took about 10 million barrels of fuel oil from the United States, while the remaining 25 million barrels found a market in other American countries. Exports to Europe, Cuba, and the West Indies are mainly from Gulf ports, while exports to Asia, Hawaii, and the west coast of South America originate in California. The principal export surplus has been in California, and part of the fuel oil from that state passes through the Panama Canal to Europe and southern South America.

4. DOMESTIC MARKETS—CONSUMPTION BY USES

A steady expansion in fuel oil consumption is characteristic of all the important uses from 1900 to 1924, as the growing supply of fuel oil increased the extent and area of its use. Since 1924 total consumption has increased more slowly, with a very irregular trend for the different uses. The marine, railroad, and gas manufacture groups have reached an almost stationary point. Consumption by oil companies and by public utility electric plants has materially declined, due to a large increase in natural gas consumption. The total decline of these groups has, however, been more than counterbalanced by a rapid expansion in the use of oil for commercial and domestic heating in the North Atlantic and Middle Western states. The large increase in crude oil production which occurred in California in 1923, about 125 million barrels, together with a continued rapid expansion in production in the mid-continent fields, resulted in a large increase in fuel oil consumption in 1923 and 1924. Further increases in consumption from 1924 to 1928 have been relatively small, especially since there has been a material decline in fuel oil prices.

(a) Oil Company Use—Production and Refining

The consumption of fuel oil by the oil industry itself, exclusive of the use by tankers which is included in marine consumption, amounts to over 14 per cent of the total fuel oil consumption in the United States. In 1928 the oil industry consumed approximately 52 million barrels, of which 46 million were used by refineries and about 6 million in oil field and pipe line operations. The first item is refinery fuel oil, and the second is largely crude oil used direct for fuel.

Consumption by oil companies was 36 million barrels in 1919, reached a maximum of 57 million in 1925, dropped to 51 million in 1926 and 46 million in 1927, and increased to 52 million in 1928. While the amount of crude oil produced and refined has increased enormously, the consumption of fuel oil required in the process has declined relatively, be-

cause of increasing fuel efficiency and use of other fuels in place of oil. In both field operations and in oil refineries located near oil and gas fields, natural gas has played an important part as a competitive source of heat and power. The great expansion in the production of natural gas in Texas and Louisiana, distant from manufacturing and domestic markets, has made this fuel available for oil company operations. Its use replaces fuel oil, which can more readily be shipped to distant markets. In operations where the natural gas must be purchased, it is largely a question of price between the two fuels. One of the reasons for the increased use of fuel oil in 1928 was its low price, which made the use of their own fuel oil output by certain refineries in the South Central states preferable to the purchase of natural gas. A similar condition in the Atlantic Coast region led to the use of more fuel oil and the purchase of less coal. The expansion in the amount of gas produced in "cracking" heavy oils is another factor of importance, as it is used largely for refinery fuel.

The principal fuels used by the oil industry and the trend in their consumption are indicated in the following table for the years 1925–1928, taken from the reports of the United States Bureau of Mines.

FUELS USED BY THE OIL INDUSTRY

	1925	1926	1927	1928
Fuel oils—million barrels				
In oil fields	4	3	2	4
By pipe lines	2	2	2	2
By oil refineries	51	46	42	46
Total	57	51	46	52
Natural gas—billion cubic feet				
In oil and gas fields	424	478	549	574
By oil refineries	88	121	123	115
Total	512	599	672	689
Refinery gases—billion cubic feet				
By oil refineries	35	52	54	77
Coal—million short tons				
By oil refineries	6.15	6.05	5.03	3.36
Petroleum coke—million short tons	0.31	0.41	0.45	0.47
Total crude oil refined—million barrels	740	779	829	913

In the reports of the Bureau of Mines the various fuels used by oil refineries are all reduced to their theoretical heat value in British thermal units to secure a common equivalent basis of comparison. The B.t.u. equivalents so used result in the following formula:[1]

1 short ton coal	=	4.33 bbls. oil	=	24,762 cubic feet of gas
@ 26 mill. B.t.u. per ton		@ 6 mill. B.t.u. per barrel		@ 1,050 B.t.u. per cubic foot

The total equivalent heat value per barrel of crude oil refined has decreased from 849,000 B.t.u. in 1919 to 813,000 in 1925 and to 637,000 in 1928, or a decrease of almost exactly 25 per cent from 1919 to 1928. The main reasons for this increased efficiency have been the recent introduction of the pipe still, which can double or treble the amount of crude oil refined without appreciably raising the fuel requirements, and the saving and use of hot gases to pre-heat the cool crude oil entering the still. The increasing amounts of refinery gas and petroleum coke used by refineries are generally indicative of the increase in the "cracking" of heavy oils to produce gasoline, as both of these products are largely the result of that process. Increasing economy in fuel consumption at refineries is very significant in view of the fact that, if all fuels used in 1925 and 1928 were reduced to terms of equivalent barrels of fuel oil, it would have required about 100 million barrels in 1925 and 95 million barrels in 1928. These amounts represent over 13 per cent of the crude oil refined in 1925 and over 10 per cent, in 1928.

The average heat required to refine a barrel of crude oil is a fair measure of the requirement of the whole industry, but gives no measure of local variations. In the Appalachian region, with smaller refineries, older equipment, and coal as the major fuel, almost twice the average theoretical B.t.u. per barrel of crude refined is used, while in inland Texas and California, with larger refineries, more modern equipment, simpler refining or topping plants, and oil and natural gas as major fuels, less than half the average B.t.u. per barrel is used.

[1] Considering the actual heat efficiency obtained in practice, this formula apparently overestimated the heat value of coal in relation to oil, as commercial estimates generally range from 3 to 4 barrels of oil to the short ton of coal.

The competitive situation between various fuels used in oil-refining is indicated by the shifts in fuel consumption from year to year. In 1926 a good market for fuel oil and an abundance of natural gas caused a decline, from 1925, of over 4 million barrels in oil consumption, over 3 million of the decrease being in Texas. In 1927 fuel oil consumption suffered a net decline of about 5 million barrels, a 2 million barrel decrease in each of three districts, the Atlantic Coast, Louisiana-Arkansas, and Texas regions, and a 1 million barrel increase in the Indiana-Illinois district. The consumption of coal declined about 1 million tons, due to increased fuel efficiency and oil consumption. Natural gas consumption increased considerably in Louisiana, at the expense of fuel oil, due to the opening of a new gas line from the Monroe field to the refining center at Baton Rouge. Increases in Louisiana were largely offset, however, by decreases in consumption elsewhere. A large part of the total decrease of fuel consumption in 1927 was attributed to the more extensive use of the pipe still. In 1928 the market for fuel oil declined, and refinery consumption increased. In Oklahoma over 1 million barrels of oil replaced about 7 billion cubic feet of natural gas. More fuel oil was used in the Atlantic Coast and Appalachian areas and together with increased pipe still development caused a decline of about 1.5 million tons in coal consumption. The recent extension in the market area for natural gas, through the construction of new long distance pipe lines to large city markets, together with the excess supply and low price of fuel oils, may cause a further increase in refinery consumption of fuel oils.

The consumption of crude oil for fuel in producing fields and by pipe lines has been small and has shown no relative increase in proportion to the increased quantity of crude oil handled. For pipe line purposes Diesel engines are quite generally used, and consequently fuel efficiency is high. In the oil fields the low consumption of oil for fuel is due primarily to the rapidly increasing use of natural gas. The gas figures given in the table represent the field use for both oil and gas production, which are usually associated closely. In 1928 the total gas so used was 574 billion cubic feet, which at the equivalent heat value of about 6,000 cubic feet to the

barrel of oil represented the equivalent of 95 million barrels of oil. While a considerable part of this consumption can not be attributed to oil production, it is obvious that any decline in gas supply would greatly increase the consumption of oil as a field fuel. On the other hand, in the event of a decline in the supply of fuel oil due to a program of larger gasoline output, the large supplies of natural gas available would probably cause a considerable substitution of this fuel in oil company operations.

(b) Marine Use—Naval and Merchant Ships

Largest Use in the United States

The most important single use of fuel oil is for the world's navies and merchant fleets. In 1928 the United States consumption for this purpose was approximately 94 million barrels, or about 26 per cent of the total fuel oil used. About 51 million barrels were used for bunkering ships in the foreign trade; 36 million, for ships in the domestic trade; and 7 million, for the navy. Of the amount supplied to merchant ships, about 31 million barrels were delivered in Atlantic Coast ports—over two thirds in New York harbor; about 16 million barrels, in Gulf ports—New Orleans, Galveston, Sabine, and Mobile; about 32 million barrels, in Pacific ports—chiefly at Los Angeles and San Francisco; and about 1 million barrels, in Hawaiian ports.

The heaviest movement of world trade is in the North Atlantic, between the United States and Europe. On this comparatively short haul, ships can readily bunker with fuel for the round trip. With the great expansion in oil-refining at the seaboard ports of the United States, fuel oil has become available at cheaper prices than in the ports of European countries, where the oil-refining industry is almost undeveloped. The United States is also favorably situated for supplying bunker oil at the Panama Canal and in Pacific Coast ports for the West Coast—South American and Asiatic trade routes. Very large import and export movements of crude and refined oil products occur in the Atlantic Coast, Gulf, and California ports. The movement is by tankers, which are themselves among the leading marine consumers

of fuel oil. These factors, together with our large coastwise trade, explain why over one half of the world's oil-bunkering is done in United States ports.

The amount of fuel oil delivered in United States ports for bunker use by ships engaged in foreign trade was less than 3 million barrels in 1914, increased slowly to 7 million in 1918, and thereafter rapidly to 14 million in 1919, 26 million in 1920, 43 million in 1924, and 52 million in 1929. Consumption in the last three years has increased slowly, even though fuel oil prices have declined. The increasing use of motor ships equipped with Diesel engines is an important factor in marine fuel economy. From 40 per cent to 50 per cent of the total oil for foreign bunkers has been supplied in the port of New York throughout the period, which indicates its predominance as a trade and oil-refining center. The Gulf ports have consistently supplied about 8 million barrels for the past five years, a large part of it as bunker fuel for tankers engaged in the export trade. The larger part of the remainder is supplied in Pacific Coast ports and has amounted to about 14 million barrels annually in the last three years.

The bunker oil used for vessels engaged in the coastwise trade increased from 16 million barrels in 1921 to about 36 million barrels in 1928. A large part of this consumption is by tankers engaged in the inter-regional shipments of oil products from the Pacific coast and the Gulf ports to Atlantic coast points for refining or consumption. Much of the increase over 1921 is due to the development of a large movement from California through the Panama Canal to east coast points.

Consumption by the United States Navy was approximately 0.5 million barrels in 1914, as the result of a long period of experimentation. During the War the navy was rapidly put on an oil-burning basis, and consumption reached 7 million barrels in 1921 and has since remained practically at that level.

Development of Marine Consumption

Fuel oil was first used for marine fuel on a large scale in the interior of Russia on the Caspian Sea and the Volga

River, where it could be readily delivered from the Russian oil fields, and later on the Pacific coast of the United States, where the increasing output of heavy crude oil in California was available. Both of these areas were isolated and could not readily deliver fuel oil to the main routes of world trade. A large and well-distributed supply was essential before any extensive adoption of fuel oil was possible for naval or international marine use.

The rapid increase in the export of heavy Mexican oil, beginning in 1911, furnished a supply readily and cheaply delivered in the eastern ports of the United States and in western Europe. Increase in oil production in the Gulf and Mid-Continent regions of the United States made large supplies of crude oil available for refining. Drawing from these supplies, a great increase in oil-refining took place in the Atlantic coast and Gulf ports of the United States, and a large volume of fuel oil became available. The opening of the Panama Canal made possible an extensive movement between east and west coast ports, with large supplies of fuel oil available at both ends of the route. Increase in oil production in the East Indies and Persia furnished a supply of fuel oil at that end of the long trade routes to Asia. These developments resulted in an extensive world movement of crude and fuel oil and the creation of a fleet of tankers to move the oil.

Thus, at the beginning of the War in 1914, adequate and very widely distributed supplies of fuel oil were available to the world market. The United States Navy, after a thorough investigation, had already decided to go on an oil-burning basis. The British navy also had been investigating the use of fuel oil for some time and had begun to convert its ships to oil-burners. Other navies have rapidly adopted the same policy. The great destruction of ship tonnage due to the submarine campaign necessitated an intensive program of ship-building, and a large number of the new ships were designed as oil-burners. Lloyd's register indicated only 3 million gross tonnage of ships on an oil-burning basis in 1914, one half of which were tankers. By 1919 this tonnage had increased to almost 9 million. In the post-war period of rehabilitation, the oil-burning tonnage, including motor

ships, increased to 18 million in 1921 and has since steadily expanded to 31 million in 1928 and 33 million in 1929, the latter figure representing about 39 per cent of the world's total merchant marine. Of the new ships launched, from 1916 to 1926 inclusive, slightly over one half were oil-burners.

The development of the marine Diesel engine has brought about a greater economy in oil-fuel utilization. In 1923 the total registered tonnage of motor ships increased from about 1 million gross tons in 1923 to over 5 million tons in 1928. If this development continues and is applied to replacements, it will make possible a continuance of oil-burning without any increase in total fuel oil requirements, as the Diesel engine requires only about 30 per cent of the quantity of oil for the same service.

The supply of fuel oil available for this expanding marine use has been maintained, in spite of a great decline in Mexican production, by increased output in the California and South Central fields, by rapid increase in Venezuelan and Colombian production, and by further expansion in East Indian and Persian oil supply.

Persistence of Marine Demand

If the supply of fuel oil should decline or the price should materially increase, the marine demand would still be a persistent bidder against users of fuel oil that might more readily revert to coal. The naval demand would be most persistent because of the greater advantages of fuel oil use and the fact that price would not be as much of a deciding factor as in the case of commercially competitive users. The rapid increase in Diesel engine installations would be an additional factor in the persistence of the marine demand, since the quantity of fuel oil required is much less. Undoubtedly, also, other economies in oil-burning would be developed. For the merchant marine, progress in fuel efficiency in burning powdered coal might facilitate a return to that fuel. In case of any considerable decline of fuel oil supply in United States ports, the first effects would be a decline in the fuel oil export trade and in the consumption of fuel oil for industrial and railroad uses. If the decline should be sufficient to turn a large part of the marine demand

back to coal, domestic coal would secure the coastwise bunker trade, but only a part of the foreign bunker trade. In the heavy North Atlantic trade between the United States and Europe, European coal would regain most of the bunker markets that were lost when fuel oil made possible round-trip bunkering in United States ports.

(c) Railroad Use—Locomotive and Shop

The use of fuel oil by the railroads represents the largest demand next to marine use. From 1902 to 1914 the railroads held first place among the consumers of fuel oil. The railroads have long been the largest consumers of fuel, and when an increased supply of fuel oil became available they naturally experimented with this fuel.

The railroad locomotive is a movable power plant, restricted in size and called upon to meet a large and constantly variable power demand due to variations in grade and load and frequent stopping and starting. The short smoke stack and the lack of combustion space make it difficult to secure high fuel efficiency. When fuel oil first became available in large quantities for railroad use, it possessed many obvious advantages over coal. More complete combustion was possible with liquid fuel. Mechanical feed eliminated the heavy labor of firing. Steam could be raised more quickly, and ease of control resulted in better adaptation to the varying power demand. Longer runs without re-fueling were possible. The elimination of flying sparks reduced the danger of fire in forested areas, and the absence of cinders added to the comfort of the passenger service. Comparatively inexpensive reconstruction will convert a coal-burning engine into an oil-burner. Another factor of significance was the poor grade of local coals in the regions where fuel oil was most available. While oil still retains many of its characteristic advantages, the position of coal has been improved by the general use of stoker-fired engines to eliminate hand firing, larger tenders to reduce the number of stops for fuel and water, and spark-arresters to eliminate the danger of fire.

The cost of fuel is an important item in railroad operation. Many railroads, particularly in the western states, owned

and operated their own coal mines and hauled their coal requirements in their own cars. The change to oil-fuel meant at least a partial shut-down of their mines. If fuel oil was available in their own territory and could be distributed over their own lines, conditions were more favorable to making the change. But, where fuel oil had to be moved long distances and over other lines, its increased cost counterbalanced the factors favorable to its use. These factors are important to an understanding of the regional use of oil as a railroad fuel and of the frequent shifts from coal to oil or from oil back to coal as the price and the supply of oil have varied.

The extensive use of oil as a railroad fuel began in 1901 on the lines operating out of California and Texas. It had already passed the experimental stage in California. Prior to this time the principal oil fields were in the Appalachian region and in Ohio and Illinois. The crude oil, which was of high grade, was refined for kerosene and lubricants with a very small production of fuel oil, which was largely absorbed by the gas companies and iron and steel plants. With the development of heavy crude oils, unsuited to prevalent methods of refining and in excess of refinery requirements in California and Texas, a large supply of heavy fuel oil became available in regions where the railroads represented the chief fuel consumers. California oil production increased from about 3 million barrels in 1899 to 24 million barrels in 1903. The development of the Spindletop oil field in Texas increased the production of that state from less than 1 million barrels in 1900 to 18 million barrels in 1902. With large supplies of cheap fuel oil available at both ends of the railroads serving the territory between these oil fields, conversion to oil-burning took place rapidly. Railroad consumption of fuel oil increased from an estimated 2 million barrels in 1900 to over 16 million barrels in 1906, to 24 million barrels in 1910, and to 34 million barrels in 1912. After the further increase in California crude oil production in 1910, fuel oil consumption was extended to the railroads operating in Oregon, Washington, and British Columbia.

From 1912 to 1915 railroad consumption remained almost stationary, due to slower expansion of oil production and

increasing demand for gasoline. A few railroad lines went back to coal consumption, but the increasing import of heavy Mexican oil and the rapid development of oil production in Oklahoma soon assured adequate supplies of fuel oil and caused a further extension of railroad consumption. In 1916 the Florida East Coast Railroad adopted fuel oil on its lines, securing a supply from Mexico. Prior to this time the zone of railroad fuel oil consumption had been largely restricted to Texas, New Mexico, Arizona, California, Nevada, Oregon, and Washington. From 1916 to 1922 railroad consumption of fuel oil increased more slowly, from about 40 million barrels to 50 million barrels, much of the increase being in Louisiana, Oklahoma, Kansas, and adjacent areas. In the North Central and North Atlantic states, railroad consumption has never been large and has been restricted to railroad shops, switching engines, and railroad ferries.

The year 1923 marked the next important upward movement in railroad fuel oil consumption and represented a response to large increases in crude oil production in California, Arkansas, Texas, Oklahoma, and Wyoming. Railroad fuel oil consumption was further extended into normal coal territory in the Middle West. Consumption jumped from 50 million barrels to 70 million barrels and remained almost stationary at that level for the five years, 1924 to 1928.

With the development of the demand for gasoline and with the change in refining methods that makes it possible to turn the heavy oils into lighter products, heavy fuel oils are no longer an essential by-product of the oil industry that must seek a market in competition with coal. The persistence—even the extension—of the railroad markets for fuel oil has been due to a total surplus oil production in recent years. Under conditions of stationary or declining crude oil production railroad fuel oil consumption would undoubtedly contract, especially in the areas of most recent extension that are nearest to available coal supplies.

California is the probable area of most persistent railroad consumption, as no adequate local supplies of coal are available and imported supplies would be relatively costly. An additional factor of importance is the long and expensive

haul to outside markets in the case of oil products from California. The high cost of local coal and the cost of shipping oil to outside markets would both react in favor of a continuance of fuel oil consumption so long as oil production is in excess of the demand for refined products. In case of shortage, railroad electrification, based on water power, would probably develop. Any marked increase in the price of fuel oil would hasten a return to Washington coal in the Puget Sound area and to local coals on most of the lines in the Rocky Mountain area, where local coal deposits are available and production has been held almost stationary for many years. In the South Central states similar conditions prevail.

Considerable progress has been made in railroad fuel efficiency in the use of oil, and with the stimulus of higher prices further progress is possible. This might retard the tendency toward abandonment of oil as a railroad fuel. Records of important oil-using railroads indicate a decrease in the oil-fuel used per unit of operation of over 25 per cent since 1920. At the end of 1928 about 20 oil-electric locomotives were in operation on the larger railroads in the United States, and about 16 others were in use mainly in large industrial plants. They are at present used for yard and switching purposes, but offer possibilities of further development and fuel economy. In Russia, the most important consumer of fuel oil for railroad purposes outside of the United States, experiments have been conducted with three main line Diesel locomotives with most satisfactory results. The progress made in the efficient use of coal in railroad locomotives has been rapid and has placed that fuel on a better competitive basis in relation to oil. In considering the general decrease in fuel consumption per unit of freight and passenger transportation, the influence of the elimination of short haul movements by the competition of trucks and bus lines must not be overlooked.

(d) Public Utility Companies—Gas and Electric

The oil consumption of this group in 1928 was approximately 30 million barrels, or between 8 per cent and 9 per

cent of the total fuel oil consumption. In the past ten years the maximum consumption was 40 million barrels in 1924. The consumption by the gas industry has been almost stationary, while that in the electric industry has been declining, although in 1929 consumption again increased, on account of shortage in water supply. The most significant reason for this decline is found in the analysis of the regional consumption of oil in these industries in relation to the expansion in the supply of natural gas. The change in consumption is least in the Atlantic Coast region, where oil from the coastal refineries can be delivered direct to large city markets in competition with coal that must be moved from interior coal fields. In this area little change is taking place in consumption, although one large electric plant in New England has gone over to a powdered coal basis.

Fuel competition in these industries is keen and of a complex character. The development of by-product ovens in the metallurgical and gas coke industries, with the consequent recovery of large quantities of by-product gases, the increasing efficiency of coal combustion and the use of powdered coal in central electric plants, and the increase in natural gas production are important factors.

Oil Consumption by Gas Industry

Oil found one of its earliest markets in the gas industry, and this use increased about fourfold from 1900 to 1919, but since that period has been almost stationary. The total amount of gas produced and purchased by the gas companies has steadily increased, from 322 billion cubic feet in 1919 to 537 billion cubic feet in 1928. The most notable recent change has been an increase in the distribution of purchased natural gas and coke oven gas. About three quarters of the oil used in the gas industry is for the enrichment or carburetion of water gas in the Eastern and Central states, and one quarter is used in the production of oil gas in the Pacific Coast states. There has been practically no recent increase in the production of either of these gases, and consequently the consumption of oil by the gas industry has remained stationary at about 23 million barrels per year, or between 6 per cent and 7 per cent of the total present fuel

oil consumption in the United States. About one half of the total oil consumed is used in the Middle Atlantic and New England states, with the North Central states and the Pacific Coast states as the other principal markets. The completion, during 1929, of a pipe line bringing natural gas to the San Francisco district will almost eliminate the consumption of oil in the manufacture of oil gas. The extension of long distance natural gas distribution to the North Central states will result in a decline in consumption there. The supply of natural gas available for both these areas is large, and an increase in natural gas consumption is, therefore, to be expected, with a continued decline in the production of gas from oil. This situation is one of several factors representing a stationary or declining demand for fuel oils due to the increasing competition of natural gas. Total coal and coke consumption by the gas industry was 12 million short tons in 1919, and had increased only to 14 million short tons in 1928. Bituminous coal increased about 1 million tons; anthracite declined 1.5 million tons; and coke increased 2.5 million tons.

Oil Consumption by Central Electric Stations

Oil consumption by central electric stations reached its peak of 17 million barrels in 1924, declined rapidly to about 7 million in 1927 and 1928, and rose to about 10 million in 1929. Coal is the main fuel used in the generation of electric power, furnishing about 90 per cent of the total fuel employed. Natural gas and fuel oil have been used in areas where coal was less plentiful. Since both of these fuels have generally been available in the same regions, the rapid expansion in the natural gas supply has been the principal factor in the decline in the use of fuel oil by the electric plants. In 1928 the distribution of oil consumption by the electric stations was about 2 million barrels each in Florida, the South Central states, and the Pacific Coast states, and about 1 million barrels in the North Atlantic states. In California fuel-electric power is largely auxiliary to water power, and production fluctuates with the annual rainfall and the water supply.

The use of electric power is increasing rapidly in the

United States. While water power is expanding steadily, the larger part of the increased output of electric power has come from fuel plants. Consumption of fuel has not, however, increased at the same rate as electrical output. Today almost twice as much power is secured from a given amount of coal as was obtained ten to fifteen years ago. This increase results primarily from greater efficiency in the use of coal by large power stations. In consequence, coal today is in a better position to compete with fuel oil, natural gas, and water power. Efficiency has been raised to such a high point that further advance in fuel economy in the best plants will be limited. In the future, progress will be made by raising the average efficiency of the industry to the efficiency of the best plants, which will involve gradual replacement of old equipment and consolidation into larger operating units. Under these conditions total fuel consumption should begin to increase and should bear a more definite relation to increasing output. With the efficient use of powdered coal, the original advantage of oil and natural gas in ease of control and handling has become a less important factor. In case of a fuel oil shortage or of a material increase in its price, coal could readily take its place where local coal supplies are available. The use of fuel oil would be most persistent in California, for reasons previously stated, and even there might be replaced, if the present large supply of natural gas should continue.

(e) Heating Use—Commercial and Domestic

The use of oil for heating buildings is expanding at a very rapid rate. For the calendar year 1928 this use was 31 million barrels, or about 9 per cent of the total consumption. Of the 31 million barrels used, 8 million are light distillate or furnace oil, and 23 million, heavier gas and fuel oil. The most rapid expansion is in the installation for small dwellings requiring a lighter grade of oil than the larger heating units in commercial buildings. Over 423,000 homes are now equipped with oil burners, and the number has been increasing at the rate of about 100,000 a year since 1927.

Oil has been used for many years for heating buildings in the Pacific Coast states, particularly California, where local

coal is less available and where a milder climate involves a shorter heating season with more variable heat requirements. Oil is particularly adaptable to such variable heat requirements because of its quick response and easy control. More than three quarters of the present consumption, however, is in the North Atlantic states and the Middle West. In these regions a long and cold winter involves a heavy and steady heat requirement. Oil has come into direct competition with Pennsylvania anthracite and with local bituminous coals, particularly the former.

The heating demand is mainly for the lighter furnace and gas oils, and this has operated to offset the stationary demand for kerosene and gas oil for other purposes. The rapid expansion in the quantity of crude oil refined has rendered available more of these lighter oils, midway between the "straight run" gasoline produced and the heavy lubricating and fuel oil residuum. This increase of lighter oils has been absorbed by the demand for heating and also by "cracking" these oils to increase the gasoline yield. Under conditions involving a stationary supply of crude oil and an increasing gasoline output, competition between the "cracking" demand and the heating demand for these lighter oils would become keener. The widening area of natural gas distribution is increasing the competition in the heating field.

The use of oil for commercial heating, which took over one half of the total consumed in 1928, requires a larger installation and a heavier grade of oil. Included in this demand are hotels, apartment houses, office buildings, schools, and churches. Oil fuel is particularly adapted for use in buildings where demand is more or less intermittent. The ease with which it can be controlled and the quickness of operation are very advantageous and more than counterbalance the added cost of fuel and installation.

One of the chief factors retarding the development of oil heating for small houses has been the high cost of installation. Undoubtedly this factor will be partially overcome with standardized equipment and increasing demand for this type of installation. The growing popularity of oil heating for dwellings is indicated by the number of installations, which increased from 13,000 in 1921 to 102,000 in 1924, and

to 423,000 for the heating season of 1929–30. Oil consumption for this purpose, including the lighter furnace distillates, increased from about 600,000 barrels in 1921 to 14 million barrels in 1928. The use of oil for house-heating presupposes willingness on the part of the consumer to pay for increased convenience. It has developed in areas of high-priced fuel, rather than in areas where cheaper bituminous coals are used for heating dwellings. These factors will make the demand for oil for this purpose more persistent than in many industrial uses, where the margin of cost between different types of fuel is a stronger determining factor.

The recent expansion in the use of oil for heating has been one of the primary causes of the decline in production and consumption of domestic anthracite coal, although the increasing use of coke produced in gas plants and the recent development of anthracite imports from the United Kingdom and Russia to the New England states and to Canada are also important factors. The increasing cost of anthracite coal, together with the serious shortage in supply during the long continued strikes in 1922 and 1925-26, has encouraged the use of substitute heating fuels.

A comparison of the statistics of the anthracite industry for 1919–1920 with the figures for 1928–1929 indicates a decline in demand of from 10 to 11 million short tons, of which 1.5 million represented a decline in exports to Canada, and the remainder, a decline in domestic consumption, consisting of about 4 million tons in the use for fuel and power by the mines and about 5 million tons in the use for house-heating. The New England market has fallen off about 2 million tons, and shipments to Great Lake points from ports on Lake Erie have declined about 3 million tons.

The market area for anthracite coal has been shrinking, particularly in those areas distant from the source of supply, where the selling price is highest and the competition of other fuels is most keenly felt. The greatest decline in consumption has occurred in the North Central states, Canada, and the coastal cities of New England, where the use of oil for heating has been increasing rapidly. The greater convenience of oil fuel has about balanced the higher cost of installation. As a result of the increasing competition of

other fuels, the anthracite producers are taking an active interest in promoting greater efficiency in the use of anthracite by household consumers. Steps are being taken to extend the use of automatic types of coal burners for house installation and to educate local coal-distributors in the most efficient methods of using anthracite.

(f) Other Manufacturing and Industrial Uses

This miscellaneous class is a large one and covers a great variety of uses, including all except the five major uses previously discussed. Its composition illustrates the diversified consumption of fuel oil in areas lacking coal, as in California, and the competitive penetration of fuel oil seeking a larger market in competition with coal, as in the Atlantic Coast area. Among the industries represented are iron and steel, mines and smelters, cement and brick, paper and pulp, automotive, food, lumber, and chemical. The total consumption in this class in 1928 was 79 million barrels. Consumption has been fairly stationary during the five years from 1924 to 1928. It had, however, increased largely in the preceding two years, when a greatly augmented supply of fuel oil was seeking a market.

Of the total consumption in this class, 79 million barrels in 1928, approximately 29 million were used in the Atlantic Coast states; 8 million, in the South Central and Gulf region; 13 million, in the North Central industrial region; only 1 million each in the Northwest Central states and the Rocky Mountain area; and 27 million in the Pacific Coast region.

The Atlantic Coast area is the largest miscellaneous consumer, with 29 million barrels in this class, out of a total fuel oil consumption in this area of 112 million barrels in 1928. The iron and steel industry used 9 million barrels, chiefly in Pennsylvania, Maryland, and New York; the textile industries of New England, 4 million; the chemical industries, 2 million, chiefly in New Jersey; mines and smelters, 2 million; the paper and pulp, ceramic, food, and automotive industries, 1 million each. This leaves about 8 million barrels for other miscellaneous purposes. These figures show a varied consumption by industries located in coastal

areas, where fuel oil can be delivered readily and cheaply from local refineries.

Miscellaneous consumption in the South Central states was only 8 million barrels, out of a total consumption of 90 million barrels in 1928. About 1 million barrels each were consumed by the mining, sugar, lumber, and cement industries, leaving about 4 million barrels for all other industries. This comparatively small consumption is explained by the lack of extensive manufacturing in the area and by competition of local coal and natural gas. Consumption in the North Central industrial region was 13 million barrels, out of a total of 33 million in 1928. The iron and steel group took 8 million; the automotive industry, 1 million; and all other industries, 4 million. This area is close to the great coal mining regions, and fuel oil has sought local markets as near to refinery locations as possible. Consumption in the Northwest Central and Rocky Mountain areas is small and widely diverse in use.

In the Pacific Coast region miscellaneous consumption was 27 million barrels, out of a total of 113 million in 1928. California used almost two thirds of the total. This large consumption is an indication of the lack of local coal supplies and the consequent reliance on fuel oil to supply the industrial demand. The cement and ceramic industries used 5 million barrels; mines and smelters, 4 million; food industries, 4 million; iron and steel, 2 million; lumber, 2 million; chemicals and pulp and paper, 1 million each; and the remaining 8 million were used by other industries.

From another viewpoint, a large part of the miscellaneous consumption is by industries using fuel in the form of heat. The iron and steel, smelter, and cement and brick plants used for heating about 34 million barrels, out of a total of 79 million. Much of the remainder represents demand for power to operate machinery. Probably the two uses are about equal in importance. In the majority of these industries coal would have served the purpose as a source of fuel and power. It is obvious that in the Atlantic Coast region and the North Central industrial area, using over one half the total, coal could be readily secured in case of a decline in fuel oil supply. California should be the most persistent

area in maintaining fuel oil consumption by this group of industries. In the iron and steel industries, which include foundries and miscellaneous plants, either coal or tar from by-product coke plants could be substituted for fuel oil if necessary. Most of these uses require less of the specialized advantages, such as fuel oil has as a marine fuel, and as a whole the miscellaneous demand could be filled satisfactorily by substitute sources of fuel or power.

5. DOMESTIC MARKET—CONSUMPTION BY REGIONS

A regional analysis of fuel oil consumption is essential to determine the local competition between oil and other available sources of energy. The persistence of local fuel oil consumption, in case of a decrease in the supply, will vary with the ease of securing substitute fuels and with the distance and cost of shipping other refined products to available markets. For example, the isolation of California from world markets for refined products and the lack of local coal supplies would tend to make that area the more persistent in fuel oil consumption. The country has been divided into six regions for discussion: the Atlantic Coast; the South Central and Gulf; the North Central; the Northwest Central; the Rocky Mountain; and the Pacific Coast. Conditions of fuel oil consumption and available supplies of coal vary greatly in these regions.

(a) Relation of Regional Fuel Oil Supply to Coal-Producing Areas

A map of the United States showing fuel oil consumption in relation to coal production indicates that the chief use of fuel oil has developed in areas outside of the main coal-producing zones, especially in coastal areas. The most productive crude oil fields are located in Oklahoma, Texas and Louisiana, and California, but crude oil is readily moved by pipe line to strategic points for refining and distribution. The present dominant factor in the location of refineries is convenience for developing either a domestic gasoline market or a tanker trade in refined products. The latter requires

a seaboard location, which enables bulk tanker movements of crude oil, fuel oil, or refined products to be carried on easily and cheaply. Refinery gas and fuel oils are, of course, marketed from the point of refining. The majority of internal movements of fuel oil, however, must be by more expensive tank car shipment. The longest hauls for fuel oil are found where a railroad purchases fuel oil for its own use and moves it over its own lines. Other commercial tank car shipments are subject to rapidly rising freight cost with increasing distance from the point of origin.

As the great interior fuel-consuming centers are in the industrial districts of the North Central states adjacent to the coal regions, the costly rail movement of fuel oil from the Mid-Continent region meets a constantly decreasing price of coal as it approaches the centers of coal production. As a result, comparatively little fuel oil from outside refineries is able to invade the coal areas proper. A considerable supply of fuel oil is available from local refineries in these areas, but Appalachian and Illinois-Indiana oils are of high grade and have always produced only a small percentage of fuel oils. Heavier crude oil has been brought in by pipe lines from the Mid-Continent oil fields to supplement the local supply for refining. A larger per cent of fuel oil has been produced from this crude oil, and this explains the considerable amount of fuel oil consumed in the Chicago industrial area. However, it has had to compete with cheap local coal, and rapid progress has been made in converting fuel oil into the more desirable gasoline by "cracking" in the refineries of this region.

In California, on the other hand, adequate coal supplies are distant and involve costly freight hauls. The chief centers of population are in the coastal areas, where pipe lines bring the crude oil for refining and for export. Expensive coal and the high cost of exporting oil products to other markets will cause the continuance of fuel oil consumption in this area longer than in either the Gulf or the Atlantic Coast area, unless local crude oil production should decline. With scarcity of oil and rising fuel oil prices, the first curtailment in consumption would occur in Oregon and Washington, where local coal supplies are available.

Expansion of hydro-electric developments could meet much of the power demand in this area if necessary.

Consumption of fuel oil in the South Central states has increased rapidly with the expansion of crude oil production in Texas and Oklahoma. Its consumption has been limited by lack of industrial and heating markets and by increased use of natural gas. Crude oil is readily piped to coastal refineries, which are more favorably located for export than those of California. The surplus crude oil of this area can be piped to North Central refineries or moved to Atlantic Coast refineries either by pipe line or tanker. This fact, in case of a general decline in crude oil production, would rapidly decrease fuel oil supply and consumption in this area. Local coal supplies are more available in this region than in California. The more persistent demand for bunker use would cause the first decline in fuel oil consumption to take place in interior markets and especially in consumption by railroads.

The North Atlantic coastal markets for fuel oil have been built up by imports and by the remarkable expansion of oil-refining due to the strategic location with reference to domestic gasoline markets in the densely populated areas of New England, New York, and Pennsylvania and to convenient facilities for the export market. Consumption of fuel oil, however, is restricted to a comparatively narrow coastal area. The largest bituminous coal fields of the country lie just west of the Appalachian Mountains in western Pennsylvania and West Virginia. Freight hauls over the mountains are expensive and mean a doubling of the cost of coal by the time it reaches the seaboard cities. On the other hand, any attempt to ship fuel oil inland by tank car means a rapidly increasing cost, while coal becomes correspondingly cheaper. The anthracite coal of eastern Pennsylvania is located very close to this consuming area. Its relatively higher cost has stimulated the competition of fuel oil, particularly in the commercial and domestic heating market. Any scarcity in oil supply for the country as a whole would affect fuel oil consumption in this area immediately. Good coal is fairly accessible and, with any material increase in fuel oil prices, it would become avail-

able. With an expansion in the large local gasoline market, the percentage of fuel oil produced by refineries would decline, and more of the crude oil would be converted into gasoline. The consumption of fuel oil for manufacturing and industrial uses would decline rapidly, but for domestic heating and bunker use it would tend to be more persistent. A decline in the bunker use of oil would not mean a corresponding increase in the market for domestic coal, as at least a part of the bunker coal would be supplied in European ports.

(b) Regional Consumption of Fuel Oils[1]

Atlantic Coast Region[2]

This region consumes about 112 million barrels annually, chiefly in the coastal cities of the North Atlantic and New England states, which are manufacturing centers with large energy requirements. Moreover, a large part of the foreign trade of the United States passes through the ports of this region, which creates an extensive demand for marine or bunker fuel.

The anthracite fields of Pennsylvania are the nearest source of coal. Anthracite coal is still the dominant domestic fuel of the region. The higher cost of anthracite as compared with bituminous coal has encouraged the competition of fuel oil for domestic and commercial uses. Bituminous coal must be brought by rail from western Pennsylvania or by rail from West Virginia to tidewater in Virginia and thence by boat to the coastal regions of Pennsylvania, New York, and New England.

The development of oil-refining at tidewater points has made available a large supply of fuel oil for local delivery in the principal markets. Crude oil for refining is assembled from various sources. The oil refining industry in this area is the greatest development of this industry in the world located at a long distance from crude oil fields. The bulk of the crude oil imported by the United States now enters the ports of this region and is handled by refineries located in the

[1] See Appendix, pp. 159–163, for tables of fuel oil consumption by regions and uses.

[2] New England, New York, New Jersey, Pennsylvania, Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida.

New England, New York, New Jersey, Philadelphia, and Baltimore districts. In addition, large amounts of domestic crude oil are moved by tanker and pipe line from the Appalachian, Mid-Continent, and Gulf fields, as well as a small amount from California via the Panama Canal. The total crude oil assembled and refined in the Atlantic Coast region in 1929, exclusive of the refineries located in the Appalachian district, was 172 million barrels, of which 106 million barrels were domestic, and 66 million barrels, imported. The refinery production of fuel oil is augmented by imports from foreign countries and by fuel oil brought by water from Gulf ports and from California.

The oil-refining industry was established in this region about 1880, when the first pipe lines were constructed from the oil fields of western Pennsylvania to bring crude oil to the seaboard. This high-grade crude oil was refined to produce kerosene and lubricants, with less than 10 per cent residuum for fuel oil. Prior to 1900 the supply of fuel oils was comparatively small, and the larger part of the output was used locally in the manufacture of gas. With the production of heavier crude oils in the coastal region of Texas from 1901 to 1909, a movement of crude oil by water routes to the refineries of this region began. This heavier crude oil produced a larger percentage of fuel oil, and with the resultant increase in supply the consumption expanded. By 1914 the expansion of crude oil production in the Mid-Continent fields of Kansas and Oklahoma had developed a pipe line movement of crude oil to the Atlantic Coast, and the rapidly increasing import of heavy crude oil by water from Mexico further augmented the supply. Much of this heavy Mexican oil was used directly for fuel without refining or after a topping process that removed from 10 per cent to 15 per cent of the lighter oils for further refining. Large and expanding sources of fuel oil were now assured, and active measures were taken to develop the market. As the supply of Mexican oil has declined, its place has been taken by increased supplies from other parts of the United States and more recently by large amounts of Venezuelan and Colombian crude oils.

Total gas and fuel oil consumption in this area in 1899 is

estimated at about 6 million barrels, or one half the total United States consumption. About 3 million barrels were used for gas manufacture, and the remainder, in oil-refining and manufacturing. By 1909 consumption had increased to about 12 million barrels, due largely to the importation of oil from the Texas Gulf region. Approximately two thirds of this total was used in gas manufacture, and the remainder in manufacturing industries. Consumption was approximately 16 million barrels in 1914, with one half of the total used by the gas industry. With the increase in Mexican imports, combined with the stimulus of war requirements and the development of bunker demand, consumption expanded rapidly and by 1919 had reached about 60 million barrels. In the last ten years it has continued to expand, although a large part of the increase occurred prior to 1925, recent consumption having remained more or less stationary at about 112 million barrels.

An analysis of consumption in 1928 indicates that, out of a total consumption of 112 million barrels, 37 million were used for bunkering ships; 15 million, by gas and electric plants; 17 million, as fuel in oil refineries; 13 million, for domestic and commercial heating; 8 million, by the iron and steel industry; 4 million, in textile manufacturing; 3 million, by railroads; and the remaining 15 million, for varied manufacturing and other uses. These figures indicate the importance of bunker fuel in the great foreign and coastwise trade of this region. The large consumption for oil-refining indicates the importance of the area as a center of refining petroleum for the domestic market as well as for the export trade. The use of oil for heating is growing rapidly, and the amount used is about 40 per cent of the total for the whole country. The small railroad consumption of this district is distinctive and is largely due to the fact that a much larger market exists here for manufacturing fuel than in most of the other fuel oil-consuming areas, where the railroads are often the chief consumers available.

Consumption in the region is largely centered in the Middle Atlantic and New England states. In 1928 New England used about 20 million barrels; New York and New Jersey, about 58 million; Pennsylvania, about 17 million; Delaware

and Maryland, about 6 million; and the remaining states to the south, about 11 million, of which Florida used 6 million.

This large fuel oil consumption has grown up in a coastal area densely populated and advanced in industrial and commercial development. Most of the oil is consumed in the port cities, and the supply can be secured direct from local refineries. In the main the price of fuel oil has been adapted to the relative cost of coal, in order to hold the industrial market. In the event of material advance in the price of fuel oil, many users would revert to coal, but the bunker demand and the growing demand for heating would probably persist, as, for these uses, oil fuel has characteristic advantages.

South Central and Gulf Region[1]

This region includes the great oil-producing areas known as the Mid-Continent and Gulf Coast fields. It is distinct from the Atlantic Coast region in that it represents large fuel oil consumption in an area with comparatively small manufacturing development and with large local oil supplies. Consumption of fuel oil is of quite different character from that in the Atlantic Coast region, and railroad, bunker, and oil company uses predominate. Recent large expansion of natural gas production in Texas and Louisiana and extension of gas lines to new markets have developed strong competition in the energy field. Natural gas is competing with oil fuel, and both are competing with the local coal mines.

Kansas, Missouri, and Oklahoma produced from 3 to 4 million tons of coal each in 1929; Arkansas produced 2 million; and Texas, 1 million. Total coal production by these states was about 13 million short tons in both 1928 and 1929, as contrasted with a coal output of 20 million tons in 1920. These figures indicate the effect of fuel oil and natural gas competition on the local coal industries.

Mississippi, Alabama, and Tennessee are unimportant fuel oil consumers. The two latter states have large coal industries, especially Alabama, and their coal production is about at the pre-war level. The small oil consumption of these

[1] Texas, Louisiana, Arkansas, Oklahoma, Kansas, Missouri, Mississippi, Alabama, and Tennessee.

states is evidence of the inability of fuel oil to move by tank cars to inland areas with local coal-mining. The expansion of the fuel oil consumption of neighboring states, however, has curtailed the market area for Alabama coal, and the recent development of long distance gas lines to Birmingham and Atlanta will add another competitive factor more important than fuel oil.

The South Central region consumed 87 million barrels of fuel oil in 1927 and about 90 million barrels in 1928, making it third in importance among the fuel oil regions. Of the total consumption, 34 million barrels were used by railroads; 23 million, by oil companies; 18 million, for naval and marine consumption; 3 million, for heating; and about 3 million, by gas and electric companies. This leaves only 9 million barrels for all other uses. These figures indicate the predominance of transportation and of the oil industry itself, and the two are, of course, closely interrelated. The mild climate of much of the area means a small demand for heating purposes and also facilitates the use of natural gas for this purpose.

In 1899 fuel oil consumption in this region was negligible, as large-scale production of oil had not started. But in 1901, with the discovery of oil on the Gulf coast of Texas, a rapid development began. The oil was of a heavy grade, and much of it was used direct as fuel or after a topping operation to produce gas oil. As the railroads were the chief users of fuel in this region, they began gradually to install oil-burning equipment, and by 1906 most of the important lines in Texas were using fuel oil. Total fuel oil consumption in 1909 is estimated at about 23 million barrels, of which probably about 10 million barrels were used by the railroads, and about 3 million barrels, by the oil industry. Experiments in marine use had been made, and some boats were burning oil, but this total consumption was relatively small in 1909. Although production declined in the Gulf field, it increased in Kansas and Oklahoma, and fuel oil consumption was extended over a wider area.

A rapid expansion in oil production in Oklahoma began about 1915, and by 1919 fuel oil consumption for the region as a whole was about 56 million barrels. Increase in con-

sumption was particularly notable in the great expansion of marine use, in the movement of oil by tankers to other markets, and in the more widespread industrial use in Kansas and Oklahoma. The area of railroad use also widened. The beginning of the movement of Mexican oil into the coastal areas forced local fuel oils to seek an inland market. Expansion continued steadily to a total consumption of 90 million barrels in 1928, as already indicated.

North Central Industrial Region[1]

This region has become a great manufacturing territory with a network of railroads serving the rich areas tributary to it. It is a large consumer of energy, chiefly in the form of coal, which it produces or obtains from the great Appalachian coal-mining areas on its eastern border. At one time its oil fields were important, but production is now relatively small, and a large quantity of crude oil is brought in by pipe lines for refining. The amount of fuel oil consumed corresponds closely with the refinery product, as the consumption of crude oil for fuel has never been of importance in this area. With the lighter grades of crude oil handled and with refineries well equipped with "cracking" facilities, the present percentage of gasoline produced is high, and that of fuel oil, low. Present fuel oil consumption represents about 9 per cent of the total for the United States.

This region was one of the early centers of oil-refining, and gas and fuel oil consumption was about 4 million barrels in 1899. The gas manufacturing, iron and steel, and oil-refining industries were the chief consumers, and in about equal proportions.

Apparent consumption of fuel oil in 1909 was only 7 million barrels and in 1914, only about 9 million. This slow expansion represented the small amount of fuel oils produced from the local crude oil, which still predominated as a source of supply in this period. In 1914 the gas industry used about 3 million barrels, and the iron and steel industry, about 2 million; the rest was used mainly for oil refining and in the glass, automotive, and cement and brick industries.

[1] Illinois, Indiana, Kentucky, Ohio, Michigan, Wisconsin.

By 1919 fuel oil consumption had reached a total of about 16 million barrels, having almost doubled in the five year period from 1914. This was due to the increasing amounts of crude oil received from the Mid-Continent fields for refining, as well as to a considerable tank car movement of fuel oil. Fuel oil consumption gradually increased to about 21 million barrels in 1926 and then more rapidly to 27 million barrels in 1927 and 32 million barrels in 1928.

In 1928 consumption by uses included over 8 million barrels by the iron and steel industry, about 8 million for heating buildings, 6 million used by oil companies, and 3 million for gas manufacture, which leaves only about 7 million barrels for other uses. Railroad consumption is negligible in this area—less than 1 million barrels for shop use.

The principal new development has been the expansion in the use of oil for heating to approximately one quarter of the total consumption. About 3 million barrels were used for commercial heating, and 5 million barrels, for domestic heating.

The present distribution of fuel oil consumption corresponds closely with the centers of refining. Illinois consumes approximately one half of the total, mostly in the Chicago district. Adjacent areas, in Indiana, Wisconsin, and Michigan, use most of the remainder, except about 5 million barrels used in Ohio. The areas of largest consumption comprise the Great Lakes industrial centers supplied by local refineries.

Fuel oil consumption in the North Central industrial region has never been relatively large. It now represents primarily the by-product of the local refining industries. The abundance of cheap coal has restricted fuel oil consumption to a limited number of uses in which it could find the best market. If progress in the refining industry further decreases the amount of fuel oils available, the consumption in this region could readily adapt itself to decreasing supply. The newest use for domestic heating would probably be the most persistent in such an event, although the widening area of natural gas distribution and the development of automatic stokers for coal-burning may be important modifying factors.

Northwest Central Region[1]

Fuel oil consumption in this region is comparatively small, a little over 3 million barrels in 1928, or less than 1 million short tons of coal equivalent. Minnesota uses about one half of the total, and most of the remainder is consumed in Iowa and Nebraska. The region depends primarily on coal as a source of energy. Local coal production is about 6 million tons, 4 million in southeastern Iowa and 2 million tons of low-grade coal in North Dakota. The larger part of the coal supply is imported from other regions, principally Appalachian coal shipped by water to Minnesota, and Illinois coal shipped by rail into the southern part of the region. Some coal moves from the Rocky Mountain fields in Montana, Wyoming, and Colorado into the western section. Coal mining in Iowa has long been in a depressed condition, due to the expansion of coal mining in Illinois. Considerable water power development has taken place in Minnesota and Iowa, but the total is equivalent to not more than 2 million tons of coal annually.

The fuel oil consumption has been too small to affect seriously the total energy consumption of the region. There is little oil-refining in this region; local supplies of fuel oil are very limited; and the comparatively expensive tank car movement restricts its use to a few special lines of consumption. The expansion of gasoline consumption to about 25 million barrels in 1928 has been a much more important factor in competition with coal in transportation service.

The present uses of fuel oil are about 1 million barrels in the manufacture of gas, 1 million in commercial and domestic heating, and 1 million in other manufacturing industries. Consumption for railroad purposes is unimportant. The use of oil in gas manufacture was the first to develop, reaching 0.5 million barrels in 1909 and increasing to 1 million barrels in 1919, but remaining almost stationary since that time. The development of the use of oil for heating has taken place since 1919 and has been the chief factor in the expansion of the total use of fuel oil from 2 million barrels in 1919 to 3 million in 1928. Oil consumption for heating is about equally divided between commer-

[1] Minnesota, Iowa, Nebraska, South Dakota, North Dakota.

cial and domestic use. About two thirds of the total is used in Minnesota. The remaining use in other manufactures has fluctuated from year to year, but shows no gain over 1919.

The comparative isolation of the region from the centers of oil production and refining and the necessity of movement by rail explain the small fuel oil consumption. The use for gas manufacture and domestic heating would be most persistent, but consumption in other lines could be replaced by coal, in case of a decline in the supply of fuel oil. The total consumption is so small that any such decline in use would represent relatively little change in the total energy consumption of the region as a whole.

Rocky Mountain Region[1]

The 1928 fuel oil consumption of this region was between 6 and 7 million barrels, roughly equivalent to 2 million short tons of the rather low-grade coals that are available in Montana and Wyoming, where the bulk of the fuel oil is consumed. The consumption of fuel oil was unimportant prior to 1912. In that year crude oil production in Wyoming began to expand. The total amount of fuel oil produced in the whole region was less than 2 million barrels in 1914, increased steadily to 7 million barrels in 1919, reached a peak of 14 million barrels in 1923, and then began to decline to about 7 million barrels in 1928 and 1929. The amount of crude oil used direct for fuel has been comparatively small, so that refinery gas and fuel oils represent the great bulk of the supply, and, since changes in stocks have been small, production of fuel oil has closely approximated consumption. In the years of greatest crude oil production, excess supply either went into increased crude oil storage, was exported to Canada for refining, or was moved by pipe lines to refining centers in the central states to the east.

Crude oil production reached a maximum of 48 million barrels in 1923 and has since declined to less than 27 million in 1929. In the latter year practically all of the product was refined in the region. From 1923 to 1929 the

[1] Wyoming, Montana, Idaho, Colorado, Utah, New Mexico.

amount of crude oil refined has been fairly constant, ranging between 25 and 29 million barrels. But, with the decline in the crude oil available and with an increasing demand for gasoline, the amount of fuel oil produced has rapidly declined from 14 million barrels in 1923 to 7 million in 1929, while the production of gasoline has correspondingly increased. Out of a total production of 16.5 million barrels of gasoline in 1929, 1.5 million were derived from natural gas gasoline, and about one half of the remainder, 7 million barrels, resulted from "cracking." Here is a concrete illustration of the results of new methods of refining that make it possible to convert a much larger percentage of crude oil into gasoline, with a corresponding decline in the production of fuel oil, when market conditions warrant the use of these methods. This change has been facilitated, for the region as a whole, by the fact that, while crude oil production has declined in the centers of largest production in Wyoming and Montana, it has increased in Colorado and New Mexico. Crude oil production for 1929 was 19 million barrels in Wyoming, 4 million in Montana, and approximately 2 million each in Colorado and New Mexico.

The development of a fuel oil supply in the Rocky Mountain area since 1912 has been one factor in causing a stationary or declining production of coal, particularly in Wyoming and Montana.

Fuel oil consumption in 1928 was approximately 6 million barrels, 4.5 million in Wyoming and Montana and about 0.5 million each in Utah, Colorado, and New Mexico. Consumption by uses indicated 1 million barrels used in oil-refining, 4 million, by railroads, and the remaining 1 million, by other industries, among which iron and steel, mines and smelters, and public utilities were the most important.

Fuel oil consumption in this region has represented the sale of a by-product in competition with local coal, particularly for railroad use. With the decline in crude oil production, its use has also declined. Practically the entire consumption of fuel oil of this region could easily be replaced by the substitution of local coal.

Pacific Coast Region[1]

This area corresponds primarily to the western distribution of California fuel oils. Surplus production has been exported to British Columbia, Asia, the Canal Zone, the west coast of South America, and, since the expansion of production about 1923, to the Atlantic Coast region via the Panama Canal.

The total fuel oil consumption of this region is estimated at about 2 million barrels in 1899, 34 million in 1909, 74 million in 1919, 99 million in 1924, 107 million in 1927, and 113 million in 1928.[2] The 1928 consumption represents about 32 per cent of the total consumption of the United States and is almost exactly the same as the amount used in the Atlantic Coast region.

This region relies on fuel oil as the major source of fuel and power. The fuel oil consumed is equivalent to the use of about 30 million short tons of coal per year. Washington is the only coal-producing state of importance in the area, and its production was only about 2.5 million tons in 1929, as contrasted with about 4 million in 1913. Some coal is shipped into the area from Wyoming, Utah, and New Mexico, and a small amount from foreign sources, but the total consumption of all coals would not exceed 4 million tons a year. Production of natural gas in California was 246 billion cubic feet in 1928, equivalent to about 10 million short tons of coal. Consumption of natural gas has increased rapidly, from 56 billion cubic feet in 1919, to 190 billion in 1924, to 212 billion in 1927, and to 246 billion in 1928. It has become an important competitive factor in the energy supply, and the recent construction of a gas line to San Francisco will extend the area of its competition. The Pacific Coast region is one of the important areas of present water power development and contains a large proportion of the undeveloped water power of the United States. About 3 million horsepower was developed in 1928, with an output of about 10 billion kilowatt hours. It would have taken

[1] California, Arizona, Nevada, Oregon, and Washington.

[2] The large use of heavy crude oil for fuel has made it necessary, in estimating past consumption, to include crude oil used direct with the refinery output of gas and fuel oils. This factor must also be considered in figures for the export of fuel oils, as prior to 1919 most of the crude oil exported was for fuel purposes.

about 9 million short tons of coal to produce an equal amount of power.

The total consumption of fuel oil, coal, natural gas, and water power in 1928 was thus about 53 million short tons of equivalent coal, of which fuel oil represented almost 60 per cent. In addition, considerable amounts of wood are used for fuel in the lumber areas in the northern half of the region. Fuel oil has played a dominant part in the industrial and commercial development of the area, and a highly competitive condition exists between different sources of energy.

Consumption of fuel oils in 1899 is estimated at about 2 million barrels, most of which was crude oil. Railroad use had already become established and took about half of the total. Use by public utilities, by cement plants, and for marine purposes was developing. The rapid expansion of heavy crude oil production after 1900 increased the total consumption to about 34 million barrels in 1909, of which the railroads used about 14 million barrels, and the gas and electric companies, about 5 million; marine use was probably 3 million; oil company use, about 3 million; and other uses, about 9 million. Consumption was largely confined to California, as probably not over 2 million barrels were used in Oregon and Washington.

By 1919 consumption had expanded to about 74 million barrels, most of the increase taking place in the first half of the period, as production from 1914 to 1919 was almost stationary. Railroad use is estimated at 27 million barrels; marine use, 10 million; use by electric companies, 6 million; gas companies, 4 million; mines and smelters, 4 million; and the oil industry, 7 million. Use for heating buildings was well developed and probably took about 3 million barrels. The balance of about 13 million barrels was widely distributed among other industries, with cement plants and sugar-refining as the most important. The area of consumption had extended soon after 1910, and by 1919 Oregon and Washington were using about 13 million barrels; Arizona, about 5 million; and California, about 55 million.

Crude oil production began to expand again in 1921 and increased from 112 million barrels in that year to 263 million

in 1923; it then dropped back to a level of about 230 million until 1929, when it again increased to 292 million. Much of this surplus was disposed of by large increases in foreign exports and by an extensive movement of crude and fuel oil to the Atlantic Coast region, which has recently changed to a gasoline movement with the increase of refining in California, due to the increased production of higher grade crude oil and to the development of "cracking" equipment.

Fuel oil consumption was stimulated in the Pacific Coast area, but could increase only with the increase in market demands, as fuel oil was already used by most of the major industries. The largest increase was in marine use and was mainly due to the increased consumption by tankers moving oil products to outside markets. Total consumption in 1924 is estimated at almost 100 million barrels and in 1928 at 113 million. Consumption in 1928 was distributed as follows: railroads, 29 million barrels; marine use, 38 million; gas and electric, 9 million; heating, 5 million; cement plants, 5 million; mines and smelters, 4 million; and all other purposes, 23 million. California used 90 million barrels; Washington and Oregon, 18 million; Arizona, 4 million; and Nevada, 1 million.

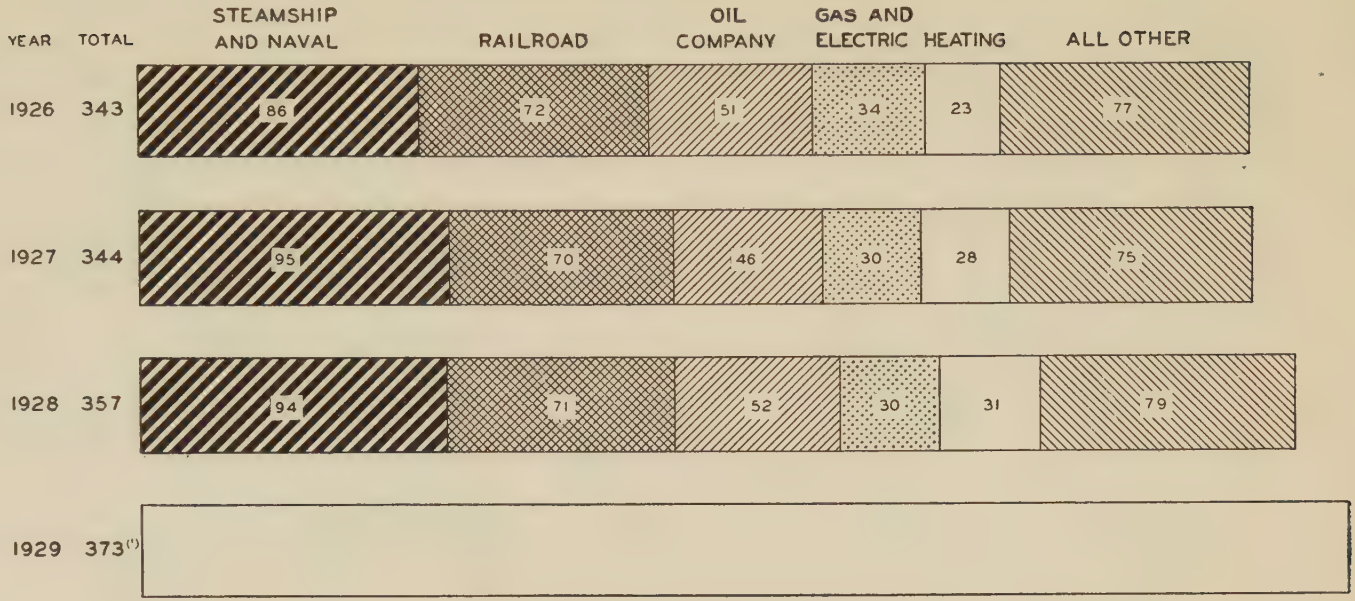
On the whole, California has had the cheapest fuel oil of all the great consuming markets. This is due to a supply of fuel oil in excess of local requirements and to the long and expensive shipment necessary to reach any important outside markets for either refined products or fuel oil. Excess fuel oil must seek a market on the Atlantic Coast, in the Canal Zone, in southern South America, or in Japan or Australia. In these markets it must compete with other world supplies. Consequently the selling price at home tends to approximate the outside price minus the cost of transportation and handling. In periods when the domestic supply has been inadequate for the Pacific Coast markets, the price has risen to approximate the price of coal substitution. In such cases, the decline in consumption was reflected in Oregon and Washington, where local coal is available and where the transportation charges of from 15 to 20 cents a barrel are added to the price in California ports.

The lack of local coal to meet the present large energy

consumption of the Pacific Coast will make this area the most persistent of all the regions in the United States in fuel oil consumption. A decline in supply would be reflected first in the disappearance of outside shipments and then in a decline of the movement to Oregon and Washington. If the supply became insufficient for California needs, coal mining in Wyoming, Utah, and New Mexico would be stimulated as well as imports of coal by water.

United States—Fuel Oil Consumption by Uses, 1926–1929

(All figures in million barrels of 42 U. S. gallons)

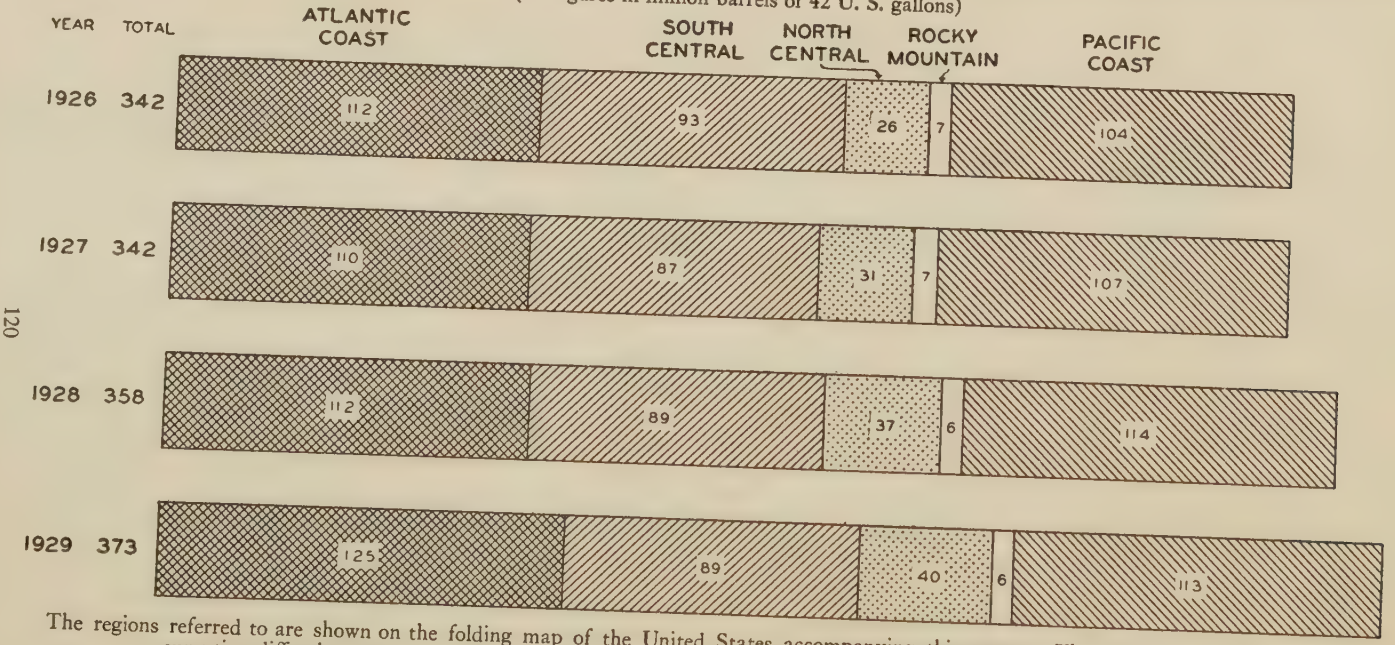


[1] 1929 total is estimated and shown for comparison.

Sources: "National Survey of Fuel Oil Distribution," published annually since 1926 by the United States Bureau of Mines.
See table in the Appendix, page 159.

United States—Fuel Oil Consumption by Regions (Including Foreign Bunker Fuel), 1926–1929

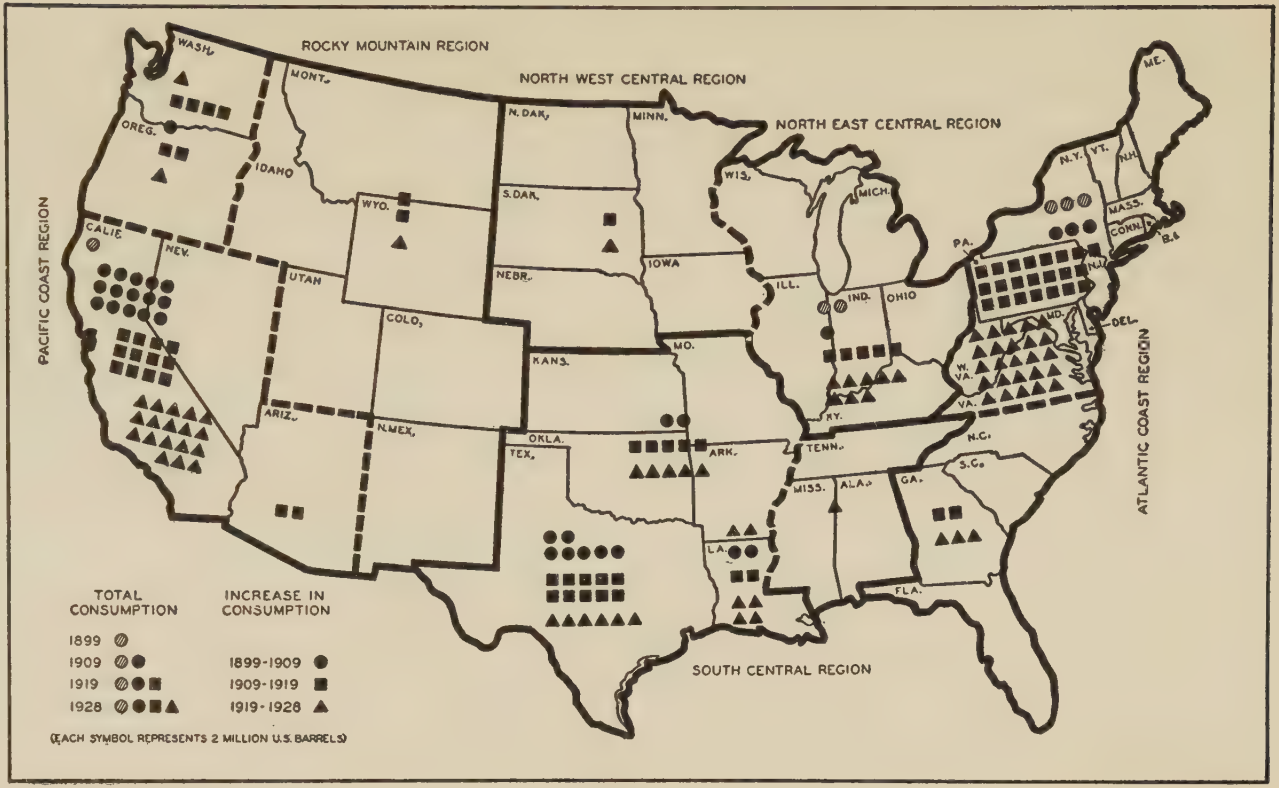
(All figures in million barrels of 42 U. S. gallons)



The regions referred to are shown on the folding map of the United States accompanying this report. The total figures of regional consumption differ by one to two million barrels from the total figures of consumption by uses due to the round numbers used and the difficulty of exactly allocating some items

Sources: "National Survey of Fuel Oil Distribution," published annually since 1926 by the United States Bureau of Mines, except for part of 1929 figures, which are estimated. See Table in the Appendix, page 160.

United States—Fuel Oil Consumption by Regions, 1899–1928



PART IV
EFFECTS OF A POSSIBLE DECLINE IN FUEL OIL SUPPLY

SUMMARY

PART IV deals with the effects of a decline in fuel oil supply under the assumed condition of a stationary output and import of crude oil. Such a decline would result if the increasing gasoline demand were met mainly by an extension in the "cracking" or other improved treatment of heavy oils now used for fuel. In view of the present prospects for increased crude oil production throughout the world, this assumed condition could arise only as the result of a program of oil conservation. Consideration of this possible situation is of value, however, in connection with the present study, because it may be regarded as certain eventually to come about. The question of the effects of a possible shortage of fuel oil is of primary interest to producers and refiners of oil, to large consumers of oil products, and to producers of competitive sources of fuel and power.

The production of a larger percentage of gasoline from heavy crude and fuel oils, made possible by improved methods, greatly increases the supply of raw material available for the more complete refining plants and insures a longer use and a more permanent character to the large investments that are involved. To the consumers of gasoline, it means assurance of a larger supply over a longer period. To the large users of fuel oil, it indicates the need for greater efficiency in use and for consideration of the ultimate availability of substitute fuels and sources of power.

The supply of fuel oils has reached its present level only because of enormous increases in crude oil production in the last few years, which have approximated a condition of overproduction. While a further increase in fuel oil supply may temporarily develop, there are grounds for believing that the period covered by the present survey is one of almost maximum consumption. This conclusion is based on the slow increase of fuel oil consumption even with the rapid decline of prices since 1927, on the increasing supply of natural gas in fuel oil consuming areas, on the assured ability to convert a larger part of the present fuel oil supply into gasoline, and

on the desirability of the extension of "cracking" in order to produce an improved motor fuel.

Producers of other fuels and sources of power have felt keenly the competition of oil products in the energy field. If crude oil production were stationary, the increase in gasoline output and the decline in fuel oil supply would shift competition from the one field to the other. However, the competition of gasoline in the transportation field is of a different character and in part represents the creation of new energy demands. The decline in fuel oil supply would relieve competition in lines of heavier fuel and power demand and would stimulate local coal and water power developments.

From the transportation standpoint, the change from fuel oil to gasoline would involve a longer haul and wider distribution of oil products and a larger movement of bulkier coal to replace fuel oil.

The effect of a decline in fuel oil supply on the consumer would be modified by expansion in the use of natural gas and by progress in the more efficient utilization of oil, which is making it possible to secure more work from the same amount of fuel.

1. RELATION OF THE CRUDE OIL CONSERVATION PROGRAM TO FUEL OIL SUPPLY

(a) Economic Significance of the Conservation Program

In December, 1924, President Coolidge created the Federal Oil Conservation Board and, in his letter constituting the Board and designating the Secretaries of the Interior, War, Navy, and Commerce Departments as members, he said:

> "Overproduction in itself encourages cheapness, which in turn leads to wastefulness and disregard of essential values. Oil, of which our resources are limited, is largely taking the place of coal, the supply of which seems to be unlimited, but coal can not take the place of oil in most of its higher uses, on land or sea or in the air."

The activities of the Board have covered the formulation of the problems involved in oil conservation and of the de-

velopment of cooperative effort between the petroleum industry and state and federal agencies. In its first report the Federal Conservation Board says:

> "The most essential products from our crude oil are lubricating oil, gasoline, and other oils for internal combustion engines. The other uses for oil could be dispensed with, without an industrial revolution, as other fuels and substitutes could be applied without prohibitive differentials in economic costs. At the present time, about one half of our crude oil production is burned either as crude oil or as fuel oil to generate steam and heat—the remainder is used as kerosene, gasoline, lubricating oil, etc. Up until thirteen years ago, the amount of gasoline which could be produced was limited to the natural fraction of gasoline in the crude product, but the discovery of cracking processes, by which the heavier oils can be broken down into gasoline, has opened an entirely new vision as to the gasoline supply."

The report points out that a better control of production would result in stimulating more efficient utilization of oil and in preventing a rush of drilling and the consequent flush production that causes a temporary glut of the market and forces much oil into fuel consumption. Active cooperation has been developed to study improved efficiency in oil production and utilization and in natural gas conservation. The Committee on World Production and Consumption of Petroleum and its Products of the American Petroleum Institute, in its first report, March, 1929, recommended that the United States production of crude oil in 1928 should be considered as the peak of requirements for 1929 and following years, and estimated that a yield of at least sixty per cent gasoline could be produced from crude oil with present known methods and proved processes. It further suggested that a study should be made to ascertain what effects and advantages would result for the coal industry, and possibly for railroads and other affected interests, if fuel oil production were to be reduced to one half of the 1928 output.

The conservation program for crude oil, consequently, seems to indicate (1) that the supply of crude oil should be considered as limited from the standpoint of future needs; (2) that motor fuel and lubricants are the most essential products, whereas fuel oils might be more readily replaced from the abundant supplies of coal available; and (3) that a

program involving an increase in the percentage of gasoline recovered from crude oil to at least sixty per cent is feasible and would result in a corresponding decline in the percentage of fuel oil produced. The program of crude oil conservation is based on the belief that the output of 1928 should be adequate, as a source of raw material, to meet the increasing demand for gasoline for several years to come. The pressure on the crude oil supply could be further relieved by converting to gasoline more of the heavy oils, now used for fuel purposes in competition with coal. Such a conservation program is of particular interest to the United States, because its present consumption of oil products is several times greater than its share of the estimated crude oil resources of the world.

(b) Changing Relation Between Gasoline and Fuel Oil

The competition of oil with other modern sources of energy is measured primarily by the consumption of gasoline and fuel oils. Together these two products constitute over 85 per cent of the present final net products of world crude oil, of which gasoline represents about 35 per cent, and fuel oil, about 50 per cent. The relation of these two products to the raw material, crude oil, has undergone a profound change since 1914. In the United States the percentage of gasoline recovered from a barrel of crude oil has risen from a little over 18 per cent in 1914 to over 37 per cent in 1928 and over 39 per cent in 1929. The increased output has resulted largely from the development of "cracking" methods for converting gas oil and fuel oil into motor fuel. If these methods should be extended to the treatment of all oil refined, it is estimated, as previously stated, that a 60 per cent recovery of gasoline would be feasible. The additional quantity of gasoline would represent a corresponding reduction in the amount of fuel oil produced.

While the cooperative conservation movement has been a factor in directing attention to the desirability of an increased output of gasoline, it should be noted that this development has a sound economic basis as a profitable operation for the

refining companies, and that a gasoline ratio very close to 60 per cent has already been attained in several refinery districts, with a steady upward trend apparent in the other districts where recovery is still relatively low. The improved and more uniform quality of gasoline produced will cause this movement to continue. The carrying out of the 1928 program of stationary crude production would only accelerate an existing trend.

In addition to the increase in "cracking" installations, a new development of significance is under way. In 1927 the commercial testing of a new process called hydrogenation was undertaken in the United States. As developed in Germany, it had been applied to the treatment of coal, but in this country it was applied to the treatment of oil. The principle of greater heat and pressure, as applied in the "cracking" process, was supplemented by the introduction of hydrogen into the refining still, which furnishes material for combination with the oil constituents to convert a larger percentage of heavy oils into lighter products. The success that has attended the research and development work has led to the construction of commercial plants and the preparation for the early operation and general licensing of the process in 1930.

The demonstrated potentialities of hydrogenation as a refining and conversion operation will have a far-reaching effect upon the petroleum industry, although progress toward its general application will be slower than was the case with "cracking," because of the many new technical problems involved and the relatively large investments required. The ultimate effect of hydrogenation, however, may be even more important than that of "cracking," as it is now shown to be possible, not only to convert coal into liquid hydrocarbons, at a cost that is not prohibitive although above prevailing oil prices, but also to secure virtually 100 per cent of high-grade finished products from the treatment of shale oil, coal tars, and crude petroleum and its residues. The production of low-grade products will no longer be necessary; refining losses will be reduced; and the oil industry will be placed on a plane of greater stability.

(c) Effect of Crude Oil Oversupply on the Fuel Oil Situation

In view of the preceding discussion it is evident that fuel oil has distinctly changed from an unavoidable by-product of oil-refining to a potential source of gasoline. In the future the fuel oil supply will be determined primarily by either shortage or oversupply of world crude oil. If a condition of oversupply of crude oil exists, the production of a larger percentage of gasoline from crude oil by new methods will be retarded, and the supply of fuel oil will be increased. If the production of crude oil is stationary or declining, the percentage of gasoline produced will increase, and the percentage of fuel oil output will decline correspondingly.

In 1928 crude oil production in the United States was kept within a reasonable relation to consumption, although total stocks of all oil products increased 23 million barrels. In 1929 world production of crude oil increased by 161 million barrels, of which 105 million were attributed to the United States. Total oil stocks in the United States increased over 68 million barrels. At the end of 1929 it was estimated that there exist in the oil fields of the world semi-settled potential crude oil resources capable of producing additional oil at the rate of about 2 million barrels a day. Probably a larger amount of proved productive oil territory is known to-day than has ever been known before. The oversupply of oil in 1929 led to an increased supply of available fuel oil and to an estimated average wholesale selling price of 89 cents a barrel in the United States, the lowest average price since 1916.

The recent rapid expansion in the supply of natural gas has further complicated this situation in the United States. The increased consumption of natural gas has taken place largely in regions of fuel oil consumption, and it has competed directly with the latter in the fuel market. Temporarily it has made the marketing of fuel oil still more unprofitable Ultimately natural gas may serve as a substitute fuel to replace a declining supply of fuel oil under improved refining methods.

The present temporary oversupply of crude oil should

not be regarded as any guarantee of a permanent increase in fuel oil supply, since the rapid expansion in total oil consumption during the last few years has attained such large proportions as to accentuate apprehension in regard to the permanence of the supply. While the great improvement in geophysical instruments has facilitated the discovery of new oil fields, their general use has led to the discovery of oil areas in excess of current demands and to the prospecting and acquiring of much of the most available oil lands. With the continued rapid expansion in the demand for motor fuel and with the ability to convert a much larger percentage of crude oil into gasoline, the oil industry now looks forward to a larger permanent supply of raw material and to the desirability of reserving it for its most efficient uses over a longer period of time. The present trend of the oil conservation movement proposes to accomplish this result through cooperation.

2. EFFECTS OF A POSSIBLE DECLINE IN FUEL OIL SUPPLY

The oil conservation program discussed by leading oil interests and by government representatives in 1929 was based on the primary object of maintaining the crude oil supply at the level of 1928 production for several years to come. For the United States, this meant approximately 900 million barrels of gross domestic production per year, supplemented by a net import of about 60 million barrels—total imports of 80 million minus exports of 19 million. Changes in stocks and estimated losses in storage and transportation reduced the total supply to about 933 million barrels, of which 913 million were run to stills and probably 20 million were used direct for fuel.

(a) Effect of a Stationary Supply of Crude Oil in the United States

The total crude oil run to stills has been taken as the basic requirement. The average annual increase in the domestic consumption of motor fuel for the five years 1925–1929 inclusive was 37 million barrels. In this period the

total supply of benzol and natural gasoline very closely approximated the net export of gasoline, so that the increase in domestic consumption corresponds to the increase in supply from refining crude oil. On the assumptions that the domestic demand for gasoline will continue to increase at the same rate for the next few years, that the supply will be obtained by "cracking" and other improved refining methods, and that the output of other products would remain the same, the effect on total gas and fuel oil output is shown in the table below. The figure for increase of domestic gasoline consumption in 1929 was 43 million barrels, and the estimate for 1930 is 38 million barrels.[1] The gas oil and fuel oil figure for 1928 represents the net output after deducting an estimate of gas oil and fuel oil diverted to "cracking" from the gross output figure usually given. The table shows that, under the conditions assumed, an increase of gasoline output to the 60 per cent ratio and a 50 per cent decline in output of fuel oil might be expected to take place in five to six years.

ASSUMED OUTPUT OF GASOLINE AND GAS OIL AND FUEL OIL IN UNITED STATES WITH STATIONARY CRUDE OIL SUPPLY ON 1928 BASIS

Figures in millions of barrels of 42 gallons

	1928	1929	1930	1931	1932	1933
Crude oil refined	913	913	913	913	913	913
A. Gasoline output from crude oil						
Straight run	219	219	219	219	219	219
Cracking	123	160	197	234	271	308
Total	342	379	416	453	490	527
Per cent of crude oil	38	42	46	50	54	58
B. Net gas oil and fuel oil produced	381	344	307	270	233	196
Per cent of crude oil	42	38	34	30	26	22
Total A and B	723	723	723	723	723	723
Per cent of crude oil	80	80	80	80	80	80

There is little probability that the situation indicated by this table will actually occur in the immediate future. Such a development might not be attainable, from a technical

[1] Report of the Committee on Petroleum Economics, made for the Federal Oil Conservation Board, March 26, 1930.

standpoint, in the short time indicated. The table serves, however, to illustrate the problem involved.

(b) Improbability of a Sudden Decline in Supply

The future supply of fuel oil will depend primarily on the trend of world crude oil production in relation to gasoline consumption. A relatively greater increase in crude oil output will maintain or increase fuel oil supply. If the demand for gasoline increases at a slower rate, due either to slower expansion in the world use of motor vehicles or to greater efficiency in the use of gasoline, the supply of fuel oil will be less affected. Higher priced gasoline, due either to shortage in supply or to the trend of gasoline taxes, would undoubtedly stimulate the development of much greater economy in consumption. Some authorities have estimated that gasoline efficiency could be more than doubled. With the present indications of expanding world crude oil production and the possibilities of greater economy in gasoline consumption, no sudden decline in fuel oil supply is to be expected. A gradual decline in supply would cause a corresponding rise in price to a point representing the actual value of fuel oil in its most advantageous uses in competition with coal. A considerable volume of present consumption, in uses for which the advantages of oil fuel are not so great, would readily and quickly revert to coal. Progress in more economical and efficient use of fuel oil has reached such a stage that the most persistent users could take care of their growing needs with the same amount of oil or even less in some cases. A contraction in consumption, from the standpoint of both uses and regional markets, would tend to reverse the trend of most recent expansion in fuel oil consumption brought about by oversupply and low prices.

When all these factors are taken into account, there appears to be no reason for concluding that a fifty per cent decline in fuel oil consumption, spread over a period of five to ten years, would cause any greater difficulties in adjustment than the recent increase in consumption over a similar period. The companies producing fuel oil would find a more valuable market for their product in the form of

motor fuel, and the producers of coal would benefit from a decline in competition and an increasing demand for their product. Increase in coal consumption would not, however, be in direct proportion to the quantitative decline in fuel oil consumption, by reason of the increasing competition of gasoline and natural gas and greater efficiency in fuel oil use.

(c) Determining Factors in Continued Consumption

The factors that determine the persistency of fuel oil consumption are: the special advantages of oil fuel for certain uses; the possibility of greater economy and efficiency in the use of fuel oil; the fact that the consumer in some cases is also a producer of some form of energy; the availability and the relative cost of substitute fuels; the degree to which the use has become established; and the cost of changing the equipment.

These factors will be considered in the discussion of a possible decline in consumption by major uses and also by regional markets. The most notable instance of special advantage of oil fuel is in marine use, and here it combines with the increasing fuel efficiency attained by the Diesel engine. The convenience of oil fuel for domestic heating is largely responsible for the rapid increase in its use for that purpose. In both of these uses the factor of relative cost of fuel is of little significance. In railroad consumption the cost factor is more important, and the ownership of oil wells or of coal mines and the possibilities of the oil-electric locomotive may be influencing factors. In the case of the oil industry itself, the fact that fuel oil is available at the lowest price for the use of the company that produces it, without any selling or transportation cost, while the opposite is true if other fuel is purchased, is an important consideration. These factors will often vary in individual cases and will modify any general statement of trends in consumption. In general, consumption will persist where regional or efficiency advantages favor oil fuel to the greatest extent, and will decline most rapidly where the margin of cost is most significant and where the markets for fuel oil have been recently established under the stress of disposing of oil at low prices.

(d) Effect on Major Uses

Analysis of the effects of a possible decline in fuel oil supply on the major uses or groups of consumers, as previously classified, indicates that marine and domestic heating will be the most persistent uses and that railroad and manufacturing groups will decline most, except in California.

Marine Use

The most advantageous and, consequently, the most persistent use of fuel oil is the marine use. Probably about 30 per cent of the total world consumption and 25 per cent of the United States total is for this purpose. Over one half of the total marine bunkering is done in United States ports. The space, time, and labor-saving advantages of oil are so great that a higher price could be paid for fuel oil than in most other uses. The rapid increase in motor ships equipped with Diesel engines is significant in that it decreases the amount of oil consumed by about two thirds. The decreased amount, as the result of this trend, should at least balance any increase in total oil-burning tonnage and might even cause a decrease in the present total requirement. World naval use is most imperative, but constitutes only about 15 per cent of the total marine demand. With the trend toward naval limitation, it shows no sign of immediate increase.

In the merchant marine the use by passenger lines and oil tankers would be the most persistent. In the former speed, time, and comfort are essential. In the latter the oil is generally the product of the company operating the tankers and is obtained at the point of production and at the cheapest cost. The least essential marine consumption is that by freight lines and tramp steamers, particularly those operating between points where coal is readily available. In this field coal has continued to be an important bunker fuel. In view of all these factors, a large part of marine demand would continue, and most of the decline in fuel oil consumption would take place in other uses.

Railroad Use

At the present time railroad consumption of fuel oil in the United States represents about 20 per cent of the total, or

about 70 million barrels a year. Railroads are among the largest consumers of fuel and have furnished a ready market for the local surplus supply of by-product fuel oils at prices generally below the level of coal competition. Under a condition of scarcity and rising prices for fuel oil, a rapid decline in consumption and a reversion to coal could be expected. Such decline might readily reach a point when only about one third the present quantity would be consumed. Use would be most persistent in railroads in the California area, where local coal is not available. Consumption should decline most rapidly in the central states, where railroad consumption has had the most recent expansion, and in the Oregon-Washington area, where local coal is available. A contraction in the zone of railroad consumption of fuel oil would benefit the coal-mining industry in practically all of the central and western states and might stimulate railroad electrification in areas with water power resources. Oil production by railroad interests in California might favor the retention of oil-fuel there, and affiliated coal-mining interests in other areas would help the return to coal. Marked improvement in the efficiency of oil consumption by railroads and developments in Diesel and oil-electric locomotives indicate possibilities of economy in areas where oil will continue to be the most available fuel. Improvements in the mechanical handling and combustion of coal by locomotives have improved the competitive position of coal.

Oil Company Use

The consumption of about 50 million barrels of fuel oil for field, pipe line, and refinery use has been a logical development where the choice has been the use of the company's own fuel oil or the purchase of outside coal, and the selling price of fuel oil has been determined by the competitive cost of coal. The use of coal as a refinery fuel is restricted to areas of low coal cost or to operations where a high grade of crude oil is used with a small output of fuel oil. Where natural gas has been available, it has been a question of the relative prices of the two fuels. The fuel economies resulting from the introduction of the pipe still and the recovery and use of still gases from "cracking" have caused a

relative decline in the amount of fuel used by refineries. The total consumption of all fuels by the oil industry has increased only at one half the rate of increase in the quantity of crude oil handled since 1925. Further economies would probably balance increased fuel requirements if all oils were more completely refined. The total fuel consumption of the oil industry in 1928 was equivalent to almost 50 million short tons of coal, of which natural gas represented 56 per cent; still gases, 6 per cent; oil fuel, 30 per cent; coal, 7 per cent; and petroleum coke, 1 per cent. Any marked decline in total fuel oil consumption will depend mainly on the continuance of large supplies of natural gas. The present consumption of coal by refineries is about 3.5 million short tons. The fuel oil consumed in Atlantic Coast refineries is equivalent to 4 million tons of coal and, in the South Central states, to 6 million tons. In case of a serious shortage of fuel oil much of this consumption might be replaced by coal where natural gas is not available, but only after most of the other industrial users had made the change and where the oil was needed for a higher priced marine market. In general, the oil company use would be relatively persistent.

Public Utility Company Use

The consumption of fuel oil by this group was 30 million barrels in 1928, or about 8 per cent of the total consumption for the United States. Gas companies used about three quarters of the group total, mainly for the enrichment of water gas, except for the use of about 5 million barrels for oil gas in California. The recent extension of natural gas lines will considerably reduce the total consumption in the Central states and California. The general use of various by-product gases has been expanding, and the ultimate development of low-temperature carbonization of coal to produce a smokeless domestic fuel may further add to the sources of gas supply. These factors indicate a probable decline in the use of oil for gas manufacture, which has remained almost stationary for the past ten years. The use of fuel oil by electric plants is largely to supply auxiliary power in times of peak load or, where water power is largely used, to supply fuel electricity in periods of water shortage. Fuel oil con-

sumption for this purpose has declined materially with the increased use of powdered coal, which has much the same advantage in quick control and adaptability. These factors indicate, for the group as a whole, that a material reduction in fuel oil consumption could be expected in case of fuel oil shortage.

Commercial and Domestic Heating

Fuel oil consumption in this group, including light distillates, was 31 million barrels in 1928, or almost 9 per cent of the total consumption. This use has been increasing rapidly, particularly for domestic heating. Convenience and competition in areas where high-cost anthracite coal is the chief domestic fuel have been the most significant factors in this development. Use for this purpose may be considered as much more persistent than are industrial uses, where the cost factor is more important and where the advantages are less. The refinery selling price of furnace oils is somewhat higher than that of Diesel oil and is much higher than that of ordinary industrial fuel oil, and the market is more desirable from the producer's standpoint.

Further improvements in oil-burning equipment and lower cost of domestic installations would favor the continuance of this demand. On the other hand, the development of automatic domestic furnaces using the smaller sizes of anthracite coal or of bituminous coal is giving those fuels more of the convenience factor. This use would probably be classed as next to marine demand in persistence, although a decline in fuel oil supply might limit its further rapid expansion. The widening area of natural gas distribution is increasing competition with oil for domestic heating in the Middle West and in California.

Manufacturing and Other Uses

These uses represent a large and varied group of consumers using a total of almost 80 million barrels of fuel oil in 1928, or 22 per cent of the total consumption. Much of it represents the endeavor to extend the market for fuel oil at low prices in competition with coal and would decline greatly

in the event of a shortage in fuel oil supply. The bulk of the oil is used for industrial heating or power purposes for which coal could be substituted. About one quarter of the total is used by the iron and steel industry, with the largest consumption in Illinois, Ohio, western Pennsylvania, and Indiana. In this area the total supply of fuel oil would be less affected, because of the present high percentage of gasoline recovery. By-product tar from coke ovens could meet part of the demand. A continued consumption of fuel oil would depend on the competition of other users. In the country as a whole. California with about one fifth the total would be the only area in which a large curtailment of consumption in this group would present serious difficulty, and even here some reduction would be possible with a further extension of water power development. A very material decline would take place in the North Atlantic coastal area. This group, together with railroad use, would show the greatest decline in consumption, which would take place in all areas outside of California.

(e) Regional Markets Most Seriously Affected

In considering the effect of a decline in fuel oil supply on regional consumption, the conclusions reached in the discussion of the major uses must be related to other factors of a local nature. More complete refining of oil for a larger gasoline yield would tend to eliminate topping operations and move more crude oil to centers of refining located in large gasoline consumption areas or at points convenient for export. The smaller amount of fuel oils produced would be available for use at these points, while the supply in outside areas would largely disappear. The predominance of coastal refining would make a large part of the fuel oil available at seaboard for the most essential marine market. The area of fuel oil consumption would thus be contracted and centralized, tending to conform to the centers of gasoline distribution. The coal-less area of California would remain the largest and most persistent consumer of fuel oil for general use and for railroad purposes. In other areas the supply would go to the marine use and to other more per-

sistent uses, such as heating, oil company use, and gas manufacture.

The relative change in the present regional supply of fuel oil would be determined by changes in the location of topping and refining plants and by the percentage of present gasoline output, as compared to the proposed increase through more extensive "cracking" and treatment. In other words, the areas with the smallest percentage of gasoline production would suffer the greatest decrease in fuel oil production. The accompanying table indicates the situation in 1928 and 1929.

PRODUCTION OF GASOLINE FROM CRUDE OIL IN UNITED STATES, 1928 AND 1929

Source: U. S. Bureau of Mines Refinery Statistics

Millions of barrels of 42 U. S. gallons

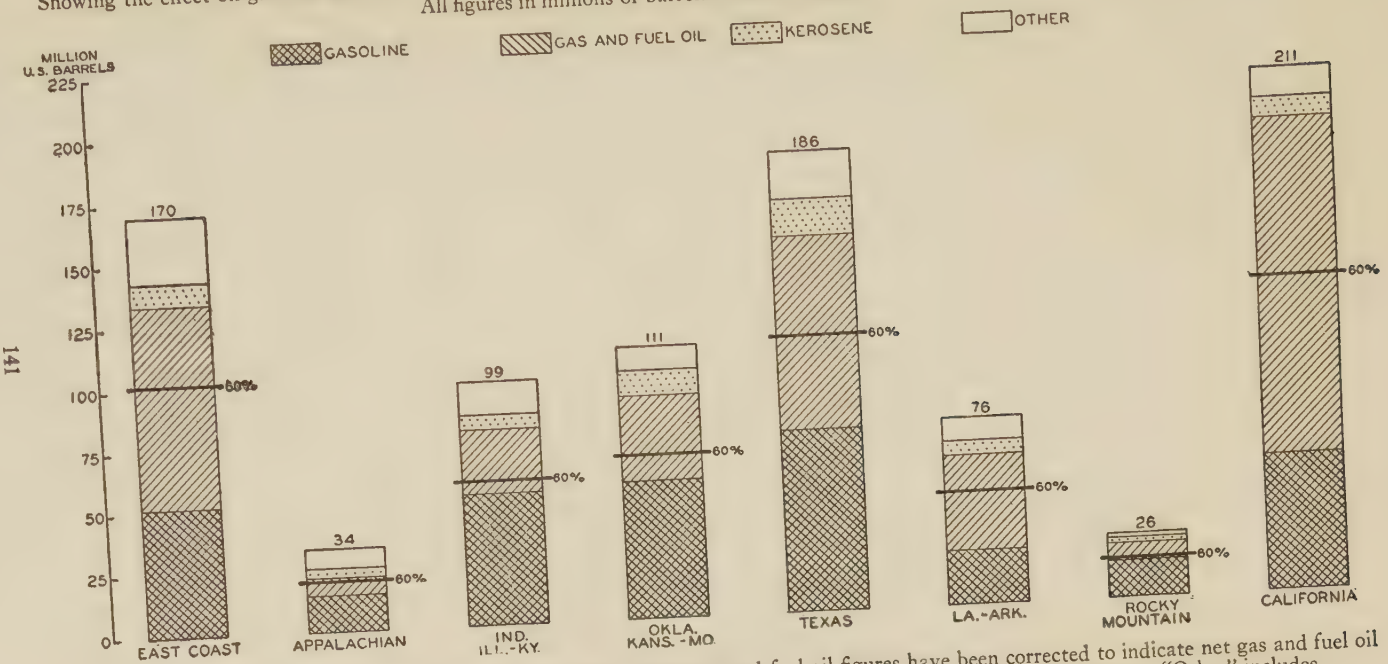
Region	Crude Oil Run to Stills		Gasoline Produced from Crude Oil		Per Cent of Gasoline to Crude Oil Refined	
	1928	1929	1928	1929	1928	1929
I. Atlantic Coast	170	172	51	56	30	33
II. Appalachian and North Central	34 99	34 110	16 53	15 62	47 54	47 56
III. Oklahoma, Kansas, and Missouri and Texas, Louisiana, and Arkansas	111 262	115 287	56 96	58 108	50 37	50 38
IV. Rocky Mountain	26	25	15	15	58	59
V. California	211	243	55	75	26	31
Total	913	987	342	389	37.4	39.4

This table indicates that a program of 60 per cent gasoline output would have comparatively little effect on the present fuel oil supply in the Appalachian, North Central, Oklahoma-Kansas-Missouri, and Rocky Mountain areas, but would seriously decrease fuel oil supply in the Atlantic Coast, Texas-Louisiana-Arkansas, and California regions. The three latter areas are the regions of present major fuel oil consumption. The chief readjustments in the use of fuel oil, according to present indications, would be decline in industrial uses in the Atlantic Coast area, large decline in export and railroad and industrial use in the South Central states, elimination of exports and shipments to Oregon and

United States Products of Crude Oil by Refinery Districts, 1928

Showing the effect on gas and fuel oil production if a 60 per cent gasoline basis was attained under a stationary crude consumption program

All figures in millions of barrels of 42 U. S. gallons



Note: Gasoline figures do not include natural gas gasoline. Gross gas and fuel oil figures have been corrected to indicate net gas and fuel oil produced in order to balance the total figure of crude run to stills, which appears at the top of each column. "Other" includes lubricants and all other finished products and shortage

United States Products of Crude Oil, by Refinery Districts, 1928

Millions of U. S. barrels

Source: The figures are based primarily on the petroleum refinery statistics of the U. S. Bureau of Mines.

Products from Crude Oil	East Coast	Appalachian	Indiana, Illinois, Kentucky	Oklahoma, Kansas, Missouri	Texas	Louisiana, Arkansas	Rocky Mountain	California	Total
Gasoline[1]	52	15	53	56	74	22	15	55	342
Gas and fuel oil[2]	82	7	27	35	78	39	7	136	411
Kerosene	9	4	6	10	15	6	2	8	59
Lubricants	11	5	4	3	8	1	1	2	35
All other	10	1	7	2	3	6	1	6	37
Shortage	6	2	2	5	8	2	1	4	29
Total crude oil refined	170	34	99	111	186	76	26	211	913
Gasoline output under a 60 per cent program	102	20	59	67	112	46	16	127	548

Note: Total figures are correct. In some cases the addition of the separate column varies by one million barrels, due to the use of round numbers to the nearest million.

[1] Gasoline figures do not include natural gas gasoline blended, but only the gasoline produced from crude oil.

[2] The figures used here are estimates of net gas and fuel oil produced. The figures generally given are gross output, part of which is re-run. For the Atlantic Coast region the correction figure used is taken from the U. S. Bureau of Mines Information Circular No. 6187, p. 6. For other regions the correction figure has been estimated.

Washington, and considerable curtailment in other uses in California.

Atlantic Coast Region[1]

This area had a fuel oil consumption, including furnace distillate, of about 112 million barrels in 1928, or 31 per cent of the total for the United States. Of the 1928 supply, about 84 million barrels were the net product of refineries in the district, and the balance represented net foreign imports of 3 million, receipts by tanker of 15 million from Gulf ports and 2 million from California, and about 6 million withdrawn from storage. The output of gasoline from crude oil was 52 million barrels, or only 30 per cent of the crude oil refined. If gasoline production were to rise to 60 per cent of the crude oil, the local output of fuel oil would shrink to 32 million barrels, and with the same supplies from other sources, except that taken from storage, there would be available about 55 million barrels of fuel oils, provided imports remained the same. Marine consumption in 1928 was 37 million barrels, and heating use was 13 million. This would leave only 5 million barrels for other uses. The decline of 57 million barrels in consumption is apparently about what would have to take place, under the assumed program, and would mean the substitution of about 16 million short tons of coal, chiefly from Pennsylvania, West Virginia, and Virginia fields.

South Central Region

This area includes the Mid-Continent and Gulf Coast oil regions and the states that derive most of their fuel oil supply from these sources. Fuel oil consumption in 1928 was approximately 90 million barrels, or 25 per cent of the total for the United States. Foreign imports of fuel oil were about 2 million barrels, and exports in 1928 were about 13 million. In addition, about 15 million barrels were shipped by water to the Atlantic Coast states, with some rail shipments to states in adjacent regions. The percentage of gasoline produced from the crude oil refined varied from 50 per cent in the Mid-Continent region to 40 per cent in Texas

[1] In the following regional summaries the figures used, though approximate, are sufficiently accurate to indicate the general factors involved.

and 29 per cent in Louisiana and Arkansas. For the region as a whole it was 41 per cent. If gasoline production were to rise to 60 per cent, net fuel oil production would decline almost one half, or from about 140 million barrels to about 70 million barrels. Under the assumptions that foreign exports would completely disappear and that rail shipments to adjacent regions would largely decline, but that shipments to the Atlantic Coast would continue at about the same rate, this would leave about 50 million barrels of fuel oil available, or 40 million less than the regional consumption in 1928. Shipments to the Atlantic Coast might further increase at the expense of local consumption. In 1928 marine consumption was about 19 million barrels, and heating use only 3 million, while railroads used 34 million; oil companies, 22 million; public utilities, 3 million; and other consumers, about 8 million. Consumption would probably decline most largely in railroad and miscellaneous uses, with some decline also in oil company use. The extent to which coal would be substituted would depend on the supplies of natural gas. If an increased supply of gas were not available, coal would be the major substitute, as there is little water power development in the area.

North Central and Rocky Mountain Regions

The present percentage of gasoline recovery is so high in these areas that fuel oil consumption is relatively small and would be less affected by a decline in the supply. In the Rocky Mountain region gasoline output in 1928 was 58 per cent of the crude oil refined; in the Indiana-Illinois-Kentucky region, 55 per cent; and in the Appalachian area, 44 per cent. The large output of lubricants from Appalachian oil leaves less opportunity for increased gasoline production, and fuel oils now represent only about 18 per cent of the output. For these areas as a whole, a 5 per cent to 10 per cent shrinkage in fuel oil supply might be expected, but it would not involve any great change in the energy situation, as total fuel oil consumption in the combined regions was only about 42 million barrels in 1928, several million of which represented a rail movement from the South Central region. It is probable that the necessity of refining more crude oil for

increased gasoline demands in this area would serve to prevent much change in fuel oil supply.

Pacific Coast Region

In 1928 fuel oil consumption was about 113 million barrels, or 31 per cent of the total for the United States, 90 million of which were used in California; 18 million, in Washington and Oregon; 4 million, in Arizona; and 1 million, in Nevada. In addition, 27 million barrels were exported to foreign countries, and about 4 to 5 million barrels were shipped to Hawaii, Alaska, and Atlantic Coast points. The total distribution was thus about 144 million barrels of fuel oil, including about 132 million barrels of refinery product and 12 million barrels of crude oil used for fuel.

Gasoline production from crude oil was 55 million barrels, or 26 per cent of the crude oil refined. Under a program of 60 per cent gasoline output, gasoline production would increase by 72 million barrels, and fuel oil supply would decline by the same amount. Even with the assumption that all exports of fuel oil would cease, this would mean a shrinkage in Pacific Coast consumption of 41 million barrels, from 113 million to 72 million, equivalent to about 12 million short tons of coal. About one half this shrinkage would take place in the movement to Washington and Oregon, and the remainder in California itself. The result would be a material increase in local coal production in Washington, Wyoming, Utah, and New Mexico and a probable increase in coal imports by water to California. Abundant water power is available in the region north of central California, and there is also a large proposed development of water power on the lower Colorado river. Natural gas production has been increasing rapidly in California and would, for a time at least, be a partial substitute for oil fuel.

In 1928 marine consumption of fuel oil was 38 million barrels; railroad use, 29 million; public utility use, 9 million; oil company use, 6 million; heating, 5 million; and other uses, 26 million. The marine use would be the most persistent, and the decline would affect most of the other uses with the greatest change in the case of consumers most distant from the refinery centers and best situated to secure coal by rail or water.

This brief regional summary roughly indicates that a decline in fuel oil use would take place mainly in the three areas of largest consumption, to the extent of 40 to 55 million barrels in each area. In all of these areas an abundant supply of heavy crude oil has led to a small percentage of gasoline output and a large supply of fuel oil. The most notable changes would be the almost complete abandonment of fuel oil in the Atlantic Coast region for all uses except for marine and heating purposes, a large decline in railroad and industrial uses in the South Central region, and a contraction in the region of California fuel oil consumption, particularly in Washington and Oregon, together with a considerable decrease in California itself.

(f) Stimulation of Other Sources of Fuel and Power

A decline of 50 per cent in the fuel oil supply in the United States, based on the situation in 1928, would mean a decrease from about 400 million barrels to about 200 million. The former figure represents a domestic consumption of about 360 million barrels and a net export of about 40 million. On the assumption that exports would be almost entirely eliminated before a serious curtailment of domestic consumption took place, domestic consumption would be reduced by about 160 million barrels, roughly equivalent to about 45 million short tons of coal. The replacement of fuel oil would be largely by coal or natural gas and, to a lesser extent, by gasoline and increased water power development. The total replacement would be modified to an appreciable extent by increased efficiency in fuel oil utilization in the more persistent uses of oil, although on the whole increasing demand and greater efficiency might be expected to offset each other. The increasing competition of fuel oil with anthracite would be retarded. The rail and water movement of bituminous coal would be increased, with resulting stimulation both of coal-mining and of the transportation agencies that distribute bituminous coal.

In the South Central region a major decline in railroad fuel oil consumption would occur, and a lesser one, in industrial use. Coal would be the major replacement fuel for

railroad use, and coal and natural gas, for industrial use. Water power resources are comparatively unimportant. The increased demand for coal would be sufficient to stimulate coal-mining in the local areas throughout the region and in the adjacent coal fields of Alabama, western Kentucky and Illinois, and Colorado, whose former area of coal distribution has been contracted by the expansion of fuel oil consumption.

In the Pacific Coast region the greatest decline in fuel oil consumption would occur in the states outside California, particularly in Washington and Oregon. Local coal from Washington would be the most important replacement fuel in this area. In Nevada and Arizona a contraction in fuel oil supply would stimulate coal-mining in Wyoming, Utah, and New Mexico. Some increased coal consumption would undoubtedly occur in California and would come from all three of the coal areas mentioned. The rapid increase in natural gas supply in California would be a factor of major importance. Large water powers, both developed and potential, are located in the Pacific Coast area, and an expansion in electrification of industries and ultimately of railroads could be expected. Imports of coal from foreign countries or from the east coast of the United States would depend on the available shipping facilities of trade tonnage and might occur when space was available in ships coming to Pacific ports for heavy cargoes. An expansion in coal demand would increase both rail and water traffic movements in the area as a whole, since coal is more bulky than oil and since increased local gasoline shipments would partly balance decreased fuel oil movements.

(g) Effect on Transportation and Traffic Movements

The major premise involved is not a decrease in the quantity of oil products moved, but a movement of more gasoline and less fuel oil. A considerable decline in local consumption of fuel oils would occur, with a correspondingly greater movement of crude oil to the more distant centers of refining and a larger distributive movement of gasoline from the major refining centers. On the whole, gasoline has a wider radius of movement than fuel oils, so that the total net mileage

movement of all oil products would be increased. In the local areas of decline in fuel oil consumption, more coal would be moved to replace fuel oil. The replacement of one ton of fuel oil would require from one and one half to two tons of local coal, varying with the quality of coal available, and would result in a considerable net increase in total fuel tonnage moved by rail. A decline in the export movement of fuel oils, particularly from California, would be offset by increased gasoline shipments. On the whole, an increase in total rail and boat movements is indicated as the result of a decline in fuel oil consumption.

(h) Significance of More Efficient Methods of Using Fuel Oil

As has been indicated, a number of factors would tend to modify and make less abrupt the effects of a decline in fuel oil supply. The present large supplies of crude oil, a slower rate in the expansion of gasoline consumption, the time necessary to install more complete refining equipment for larger gasoline output, and greater efficiency in the use of fuel oil would all be factors in the situation. In this connection it should be emphasized that, while a rapid decline in fuel oil supply might take place under conditions of an acute shortage in crude oil supply or under a world-wide policy of restriction of production to the amount required for most essential uses, an assumption of any sudden change in fuel oil supply is purely speculative and has been made primarily to consider the most essential uses of fuel oil and the present areas of consumption most dependent on it as a source of energy. The trend of greater efficiency in the use of fuel oils is a part of a wider movement in research and improvement in the use of energy, which has been especially active during the War and post-war periods and has received much of its stimulus from a higher level of prices. Any decline in fuel oil supply, with rising prices, would similarly tend to stimulate further improvements and economies in its use. Much progress has been made in the improvements in furnaces and engines using oil, and the extension of the adoption and use of such equipment would be hastened under the stimulus of decreased supply.

APPENDIX

THE COAL EQUIVALENT OF OTHER FORMS OF ENERGY

SOME formula is essential to reduce the various major forms of energy to a common basis for comparison. Such a formula can be only approximate because of the variation in the heat content of different grades of coal, oil products, and gas and of the varying efficiency in their use.

Since coal is by far the most important and largest present source of energy, it seems most useful to attempt to measure roughly other forms of energy in terms of coal equivalent. This necessitates, in the first place, that a standard grade of good average coal be taken for purposes of comparison. A coal of about 13,000 B. t. u. per pound seems to be generally accepted as representing a fair average of quality. In the United States the average quality of coal mined closely approximates the above standard. In countries where large amounts of lignite or low-grade brown coals are mined, their gross tonnage must be reduced to a bituminous equivalent for comparison. In determining total world coal output, German brown coal has been converted at the ratio of 4.5 tons of brown coal to 1 ton of good bituminous coal, following the practice of German statistical publications. For other lignite coal the ratio of 2 tons to 1 of bituminous is used. With this method of reducing various qualities of coal to a standard, the problem remains of the relation of other forms of energy to coal.

The formula of relationship used for the purposes of this report is

(a) 1 metric ton of coal = 4.0 U. S. barrels of oil = 25,000 cu. ft. natural gas.

or

(b) 1 short ton of coal = 3.6 U. S. barrels of oil = 23,000 cu. ft. natural gas.

This compares with the following theoretical heat value formula:

1 short ton of coal =	4.2 bbls. oil	= 25,000 cu. ft. nat. gas.
@ 13,000 B. t. u. per lb.	@ 6.2 mill. B. t. u. per bbl.	@ 1050 B. t. u. per cu. ft.
26 mill. B. t. u.	@ 26 mill. B. t. u.	26.2 mill. B. t. u.

The reason that the theoretical ratio is not used is because actually oil and gas are more efficient in use than coal. Where powdered coal is used, the relation of coal approaches the theoretical, as the conversion ratio used by the Geological Survey for equating fuels to a common term, based on the average practice of public utility electric plants, showed one short ton of coal as equal to 4.2 barrels of oil and 23,000 cubic feet of natural gas. The total use of powdered coal, however, is as yet relatively small.

The Minerals Division of the Bureau of Foreign and Domestic Commerce uses the ratio of 4 barrels of oil as equivalent to one metric ton of coal in its fuel and power studies. The railroads in the United States use 160 gallons of fuel oil, 3.8 barrels, as an average equivalent of 1 short ton of coal, although the experience of one of the largest railroad consumers indicates less than 3.5 barrels in practice. For purposes of world comparison, therefore, the formula here used seems fairly accurate in view of current practice, especially when the figure is used to equate the net products of oil—fuel oil, gasoline, and kerosene—rather than the total crude oil produced. Round numbers are used for convenience. Approximately 6,000 cubic feet of natural gas has been taken as equivalent to one barrel of oil.

The equation of water power to coal has been made on the basis of the amount of coal required to produce the same amount of electricity under current practice. A computation of the world production of electricity from water power in 1928 indicated from 110 to 115 billion kilowatt hours output. Using 1.8 pounds of coal for the United States and Canada and 2.2 pounds for other countries, or an average of 2.0 pounds for all countries, the equivalent of water power was about 115 million short tons of coal, or roughly 3 short tons to the developed horsepower. This ratio is used in the charts and diagrams of this report for 1928 and 1929 figures.

World Energy Consumption,[1] 1928–1929

Fuel for ships' bunkers is included with consumption

Region	Coal[2] Million Short Tons Lignite Reduced to Bituminous Equivalent		Fuel Oil Million Barrels		Gasoline[3] Million Barrels		Kerosene Million Barrels		Natural Gas Billion Cubic Feet		Developed Water Power Dec. 31, 1928. Million H. P.
	1928	1929	1928	1929	1928	1929	1928	1929	1928	1929	
Canada and Newfoundland	33	34	14	16	14	17	2	2	22	28	5.6
United States, Alaska and Hawaii	572	589	360	376*	331	375	36	36	1,568	1,917	13.6
Total—United States and Canada	605	623	374	392	345	392	38	38	1,590	1,945	19.2
Caribbean	3	3	44	44	4	5	2	2	..	..	0.4
East Coast South America	6	6	18	20	7	9	2	2	..	..	0.6
West Coast South America	2	2	9	9	1	1	1	1	..	..	0.2
Total—Other America	11	11	71	73	12	15	5	5	..	..	1.2
United Kingdom and Ireland	209	220	24	22	26	28	4*	4*	0	0	0.3
Other North Europe	424	463	18	20	31	38	10	10	16	17	10.0
Total—North Europe	633	683	42	42	57	66	14	14	16	17	10.3
South Europe and North Africa	37	40	18	21	9	11	7	8	25	25	4.9
European Russia	35	42	48	50	1	1	9	12	11	12	0.3
Total—Mediterranean	72	82	66	71	10	12	16	20	36	37	5.2
Southern Africa	16	16	1	2	2	3	1	1	0	0	0
South Asia	30	30	26	26	5	5	12	11	19	20*	0.3
Australia—New Zealand	18	17	3	3	7	8	2	2	0	0	0.3
Total—South Asia—Africa	64	63	30	31	14	16	15	14	19	20	0.6
Total—North Asia	70	70	11	12	2	3	8	9	..	..	2.5
Total—World	1,455	1,532	594	621	440	504	96	100	1,661	2,019	39.0

[1] No adjustment has been made for changes in storage except for the United States.

[2] German brown coal has been converted to bituminous coal equivalent on the basis of 4.5 tons of brown coal to 1 ton of bituminous and other lignites on the basis of 2 tons to 1.

[3] Includes natural-gas gasoline, but not benzol.

* Estimated.

Note—The regions indicated in this table are shown in the world map accompanying this report.

World Energy Consumption, 1928

Reduced to equivalent of coal
Million short tons

	Coal	Fuel Oil	Gasoline	Kerosene	Natural Gas	Water Power	Total Coal Equivalent
United States	572	100	92	10	68	41	883
North Europe	633	12	16	4	1	31	697
All Other	250	53	14	13	3	45	378
Total World	1,455	165	122	27	72	117	1,958

World Coal Production

Million short tons. Lignite reduced to bituminous coal equivalent.

Sources: Compiled from the report of the German Federal Coal Council, "Statistische Uebersicht ueber die Kohlenwirtschaft im Jahre 1929," and from Mineral Resources, U. S. Bureau of Mines.

Year	I. American Zone			II. Europe, Including Turkey			III. All Others	World
	United States	Other Americas	Total	United Kingdom	All Others	Total	Africa, Asia, Oceania	Total
1909	460	13	473	295	319	614	62	1,149
1910	502	16	518	296	321	617	69	1,204
1911	496	15	511	305	332	637	74	1,222
1912	535	17	552	292	361	653	80	1,285
1913	570	18	588	322	386	708	88	1,384
1914	514	17	531	297	315	612	91	1,234
1915	532	16	548	284	285	569	90	1,207
1916	590	17	607	287	309	596	95	1,298
1917	651	17	668	279	320	599	104	1,371
1918	678	18	696	255	289	544	108	1,348
1919	553	16	569	257	251	508	113	1,190
1920	658	18	676	257	293	550	112	1,338
1921	506	16	522	183	310	493	108	1,123
1922	477	16	493	280	325	605	110	1,208
1923	658	19	677	309	276	585	119	1,381
1924	572	16	588	299	351	650	124	1,362
1925	582	15	597	273	371	644	128	1,369
1926	658	19	677	142	418	560	133	1,370
1927	598	19	617	282	444	726	135	1,478
1928	576	19	595	266	447	713	132	1,440
1929	608	19	627	288	484	772	131	1,530

Crude Petroleum—World Production, by Regions, 1909–1929

Sources: 1909–1928—U. S. Bureau of Mines, Mineral Resources; Petroleum in 1928. 1929—Mimeograph U. S. Bureau of Mines, U. S. Bureau of Foreign and Domestic Commerce reports, and trade journals.

Million U. S. barrels

Year	I. American Zone				II. Europe, Including Egypt			III. Asia				World
	United States	Mexico	Other Americas	Total	Russia	Others	Total	Dutch East Indies	Persia	Others	Total	Total
1909	183	3	2	188	66	25	91	11	0	9	20	299
1910	210	3	2	215	70	24	94	11	0	8	19	328
1911	220	13	2	235	66	23	89	12	0	8	20	344
1912	223	17	2	242	68	23	91	11	0	9	20	353
1913	248	26	3	277	63	22	85	11	2	10	23	385
1914	266	26	3	295	67	21	88	11	3	10	24	407
1915	281	33	4	318	69	18	87	12	4	11	27	432
1916	301	40	5	346	66	16	82	13	4	12	29	457
1917	335	55	6	396	63	12	75	13	7	12	32	503
1918	356	64	6	426	27	17	44	13	9	11	33	503
1919	378	87	7	472	32	15	47	15	10	12	37	556
1920	443	157	7	607	25	15	40	18	12	12	42	689
1921	472	193	10	676	29	16	45	17	17	12	46	767
1922	558	182	13	753	36	17	53	17	22	14	53	859
1923	732	150	17	899	39	19	58	20	25	14	59	1,016
1924	714	140	27	881	45	21	66	20	32	15	67	1,014
1925	764	115	41	920	52	26	78	21	35	15	71	1,069
1926	771	90	68	929	64	32	96	21	36	16	73	1,098
1927	901	64	103	1,068	77	34	111	28	40	15	83	1,262
1928	902	50	156	1,108	88	39	127	32	44	17	93	1,328
1929	1,007	45	192	1,244	103	43	146	38	42	18	98	1,488

World Fuel Oil Consumption by Regions[1]

1. American Zone[2]

Million U. S. barrels

	1924	1925	1926	1927	1928	1929
North America						
Canada	8	8	9	11	14	16
United States	350*	340*	343	344	358	373*
Alaska and Hawaii	3	4	3	3	2	3
Total	361	352	355	358	374	392
Caribbean						
Mexico	22	18	18	15	13	11
Panama Canal	6	6	6	8	8	7
Central America	1	1	1	1	2	2
Cuba	8	9	6	6	5	5
Netherlands West Indies*	1	3	4	5	7	8
Other West Indies	2	3	3	3	4	5
Venezuela*	1	1	2	2	3	4
Columbia	0	0	1	1	2	2
Total	41	41	41	41	44	44
Eastern South America						
Argentina	8	8	9	12	14	16
Uruguay	1	1	1	1	2	2
Brazil	2	2	2	2	2	2
Total	11	11	12	16	18	20
Western South America						
Chile	6	6	5	5	7	7
Peru, Bolivia, Ecuador	2	2	2	2	2	2
Total	8	8	7	7	9	9
Total—American Zone	421*	412*	415	422	445	465*

[1] Including bunker oil.

[2] The figures are primarily based on the following sources. Statistics of importing countries have been checked by those of exporting countries and have been supplemented by estimates of items of local refinery production and consumption.

Sources: "International Trade in Petroleum Products," U. S. Bureau of Foreign and Domestic Commerce, Trade Promotion Series, Nos. 80 and 99. "National Fuel Oil Survey," U. S. Bureau of Mines, 1926, 1927; 1928; "Monthly Foreign Petroleum Statistics," U. S. Bureau of Foreign and Domestic Commerce.

* Estimated.

2. European—Mediterranean Zone

Million U. S. barrels

	1924[1]	1925	1926	1927	1928	1929
North Europe						
United Kingdom	20.0	18.5	21.6	24.4	23.6	21.9
France[2]	4.0	4.3	4.8	5.6	5.8	6.4
Belgium and Netherlands	2.0	1.7	2.6	3.1	2.9	3.4
Switzerland	0.2	0.3	0.3	0.3	0.4	0.4
Germany	2.0	2.2	2.6	3.5	4.1	4.2
Denmark	0.5	0.6	0.8	0.9	1.0	1.0
Norway, Sweden, Finland	1.0	1.1	1.3	1.4	1.5	1.8
Other Northern European	0.8	0.8	1.1	1.3	1.7	1.8
Total	30	30	35	41	42	42
Mediterranean—Russian						
Spain and Portugal	0.4	0.4	0.4	1.4	1.8	2.4
Italy[3]	4.9	4.9	5.5	5.8	6.3	7.2
Rumania	5.0	6.0	7.0	7.3	7.7	8.6
Other Southern European	0.3	0.4	0.6	0.8	0.8	0.9
Egypt and Suez	1.2	1.2	1.2	1.2	1.0	1.2
Other Western African	0.2	0.2	0.2	0.3	0.3	0.3
Total Mediterranean	12	13	15	17	18	21
Russia[4]	31	29	40	41	48	50
Total	43	42	55	58	66	71
Grand Total	73	72	90	99	108	113

[1] Figures for 1924 have been estimated in part.

[2] French figures include an estimate of about 2 million barrels a year for naval use, which is not included in commercial imports.

[3] Italian figures include an estimate for naval and foreign bunker use, which are not included in commercial imports.

[4] Russian figures are approximate and include crude oil used for fuel without refining.

3. South Africa—Asia-Oceania Zone

Million U. S. barrels

	1924	1925	1926	1927	1928	1929
Australia	1.0	1.0	1.3	1.8	1.5	2.4
New Zealand	0.6	0.6	1.1	0.9	1.1	0.8
Total	2	2	2	3	3	3
China and Hongkong	1	1	1	1	2	2
Japan[1]	5	6	7	8	9	10
Total	6	7	8	9	11	12
Philippines	1.5	1.5	1.2	1.0	1.0	1.0
Dutch East Indies[1]	4.0	4.0	4.0	5.0	5.0	5.0
British Malaya	2.0	2.0	3.0	3.0	4.0	4.0
Siam and Indo-China	0.2	0.2	0.2	0.3	0.3	0.3
Total	8	8	8	9	10	10
India	7.0	7.0	7.0	7.0	7.0	7.0
Ceylon	1.0	1.1	1.4	1.5	2.0	2.0
Persia[1]	4.0	4.0	5.0	5.0	5.0	5.0
Aden	1.3	2.0	2.1	2.3	2.2	1.6
Total	13	14	15	16	16	16
South Africa	0.4	0.5	0.8	1.0	1.3	1.6
Grand Total	29	32	34	38	41	43

[1] Complete figures for the Dutch East Indies, Japan, and Persia are not available, and only approximate figures are given, based on estimated refining and marine use.

United States Consumption of Fuel Oil by Uses, Including Crude, Gas, and Fuel Oils

In million barrels of 42 U. S. gallons—figures to the nearest million

Sources: The figures for 1926 and later years are from the annual "National Survey of Fuel Oil Distribution," prepared by the United States Bureau of Mines. The totals differ from that publication, due to the inclusion of fuel used by pipe lines and of furnace distillate used for domestic heating.

The figures for 1924 and 1925 are from the reports of the U. S. Bureau of Mines and the publications of the American Petroleum Institute.

	1924	1925	1926	1927	1928	1929
Used on oil leases	4	4	3	2	4	4
Used by pipe lines	2	2	2	2	2	2
Used as refinery fuel	..	51	46	42	46	52
(a) Total used by oil companies	..	57	51	46	52	58
Used by United States Navy	7	7	7	7	8	6
Used for domestic bunkers	38	30	32	38	40	41
Used for foreign bunkers	43	43	47	50	50	51
(b) Total marine use	88	80	86	95	98	98
Used by locomotives	62	60	62	60	63	66[1]
Used by railroad shops and ferries	11[1]	11	10	10	8	10
(c) Total railroad use	73	71	72	70	71	76[1]
Used by electric power companies	17	10	10	7	7	10
Used by gas companies	24	23	24	23	23	21
(d) Total public utilities	41	33	34	30	30	31
Used for commercial heating	..	12	14	16	17	18
Used for domestic heating, including distillate	5	9	9	12	14	18
(e) Total heating use	..	21	23	28	31	36
Used by iron and steel industry	..	..	16	18	19	20
Used by mines and smelters	..	..	9	7	7	7
Used by cement and ceramic industries	..	..	9	8	8	6
Used by food industries	..	..	8	7	6	7
Used by paper, pulp, and lumbering industries	..	..	6	6	5	5
Used by textile industries	..	..	5	5	5	5
Used by all other industries	..	..	24	24	31	32
(f) Total other manufacturing and industrial uses	..	77[2]	77	75	81	82
Total all uses as above	..	339	343	344	363	381[1]

[1] Three million barrels of this represent increase in stocks rather than consumption. [2] Estimated.

Note: The tables on pages 159, 160, 162, 163, and 164 have been revised for 1928 and completed for 1929 to agree with the final 1929 report of the Bureau of Mines, which was not available for the first edition of this book. Some discrepancies will appear in the text, which has not been revised. The 1928 revised figures show a total of 363 million barrels as compared with the previous figure of 357 million. Of this increase about 4 million barrels were for marine use in the Southern States, and 2 million, for industries in the North Central States. All other figures are essentially the same.

United States Consumption of Fuel Oil by Regions and Uses

United States Consumption of Fuel Oil by Regions

Million U. S. barrels

District	1926	1927	1928	1929
Atlantic Coast region				
New England	20.9	20.9	18.7	21.8
Central District[1]	77.1	77.1	82.3	90.5
Southern District[2]	12.3	9.9	7.9	8.2
Furnace oil, unallocated	2.0	2.2	2.9	4.8
Total	112.3	110.1	111.8	125.3
South Central region				
Eastern[3]	1.9	1.2	1.5	1.7
Western[4]	89.5	83.8	88.7	94.3
Pipe line fuel	2.0	2.0	2.0	2.0
Total	93.4	87.0	92.2	98.0
North Central region				
Eastern[5]	19.0	24.4	30.9	30.6
Western[6]	2.5	2.9	3.1	3.5
Furnace oil, unallocated	4.0	4.0	5.0	6.0
Total	25.5	31.3	39.0	40.1
Rocky Mountain region	6.8	7.2	6.0	6.0
Pacific Coast region				
California, Arizona, Nevada	90.9	93.3	96.5	94.8
Oregon, Washington	13.5	13.5	17.6	18.1
Total	104.4	106.8	114.1	112.9
Grand Total	342	342	363	382

[1] From New York to Virginia inclusive.
[2] From North Carolina to Florida inclusive.
[3] Alabama, Mississippi, Tennessee.
[4] Texas, Louisiana, Arkansas, Oklahoma, Kansas, Missouri.
[5] Kentucky, Ohio, Indiana, Illinois, Michigan, Wisconsin.
[6] Minnesota, Iowa, Nebraska, North and South Dakota.

Source: Compiled from "National Survey of Fuel Oil Distribution," United States Bureau of Mines, except for the estimates.

1. Atlantic Coast Region

Million U. S. barrels

District or State	1926	1927	1928	1929
New England	20.9	20.9	18.7	21.8
New York	36.0	34.3	37.0	38.3
New Jersey	14.9	19.7	20.0	22.5
Pennsylvania	17.3	14.5	16.2	19.9
Delaware	0.9	0.6	0.5	0.9
Maryland	5.3	5.1	5.9	6.0
District of Columbia	0.8	1.0	1.0	1.2
Virginia	1.5	1.5	1.2	1.3
West Virginia	0.4	0.4	0.5	0.4
North Carolina	0.3	0.2	0.2	0.2
South Carolina	1.3	1.0	0.8	0.7
Georgia	1.5	1.3	1.3	1.3
Florida	9.2	7.4	5.6	6.0
Total	110.3	107.9	108.9	120.5
Furnace oil, for heating, unallocated	2.0	2.2	2.9	4.8
Total	112.3	110.1	111.8	125.3
Use				
Steamship and naval	33.3	35.8	36.7	39.7
Railroad	4.3	3.4	2.7	2.7
Gas and electric company	16.7	15.2	14.8	15.6
Commercial heating	6.7	7.5	7.3	7.6
Domestic heating	3.3	4.5	5.7	8.1
Oil company	15.5	14.0	16.4	17.5
Iron and steel product	9.2	8.9	8.4	9.7
Textile	*	4.2	4.2	4.6
All other	23.3	16.6	15.6	19.8
Total	112.3	110.1	111.8	125.3

Source: Compiled from the "National Survey of Fuel Oil Distribution," United States Bureau of Mines.

* Included in all other.

2. South Central Region

Million U. S. barrels

District and State	1926	1927	1928	1929
Eastern				
Alabama	1.1	0.4	0.4	0.7
Mississippi	0.4	0.3	0.3	0.2
Tennessee	0.4	0.5	0.8	0.8
Total	1.9	1.2	1.5	1.7
Western				
Louisiana	20.7	18.2	17.5	18.5
Texas	48.0	44.5	48.2	50.2
Arkansas	1.8	2.2	2.5	2.6
Oklahoma	8.7	8.8	10.3	12.4
Kansas	5.2	4.8	5.7	5.6
Missouri	5.1	5.3	4.5	5.0
Pipe line fuel, unallocated	2.0	2.0	2.0	2.0
Total	91.5	85.8	90.7	96.3
Grand total	93.4	87.0	92.2	98.0
Use				
Railroad	31.5	32.8	34.0	38.5
Oil company	24.8	19.7	22.6	26.9
Steamship and naval	17.9	19.5	21.8	19.3
Gas and electric	3.7	2.5	2.9	2.5
Commercial heat	1.9	1.2	1.8	1.6
Domestic heat	0.4	1.0	0.4	0.3
All other	13.2	10.3	8.7	8.9
Total	93.4	87.0	92.2	98.0

Source: Compiled from the "National Survey of Fuel Oil Distribution," published by the United States Bureau of Mines, unless otherwise indicated.

3. North Central Region

Million U. S. barrels

District and State	1926	1927	1928	1929
Eastern				
Ohio	3.1	3.9	4.8	4.8
Kentucky	0.3	0.4	0.4	0.4
Indiana	3.1	4.3	5.0	5.6
Illinois	9.0	11.4	14.1	13.4
Michigan	2.4	3.0	5.1	4.8
Wisconsin	1.1	1.4	1.5	1.6
Total	19.0	24.4	30.9	30.6
Western				
Minnesota	1.0	1.4	1.5	1.5
Iowa	0.7	0.7	0.8	0.9
Nebraska	0.7	0.7	0.6	0.8
North Dakota	0	0	0.1	0.1
South Dakota	0.1	0.1	0.1	0.2
Total	2.5	2.9	3.1	3.5
Furnace oil, for heating, unallocated	4.0	4.0	5.0	6.0
Grand total	25.5	31.3	39.0	40.1
Use				
Iron and steel	5.1	6.8	8.5	7.3
Oil company	3.2	5.0	6.0	6.7
Commercial heating	1.4	2.1	2.4	2.3
Domestic heating	5.1*	7.0	7.8	9.3
Gas and electric	3.8	3.7	4.6	4.7
Railroad	0.6	0.7	0.9	1.1
Steamship	0.4	0.3	0.2	0.1
All other	5.9	5.7	8.6	8.6
Total	25.5	31.3	39.0	40.1

Source: Compiled from the "National Survey of Fuel Oil Distribution," except as indicated.

4. Rocky Mountain Region

Million U. S. barrels

State	1926	1927	1928	1929
Montana	2.4	2.8	2.2	2.2
Wyoming	3.2	2.7	2.4	2.4
Idaho	0.1	..	..	..
Utah	0.4	0.4	0.4	0.6
Colorado	0.4	0.9	0.6	0.4
New Mexico	0.3	0.4	0.4	0.4
Total	6.8	7.2	6.0	6.0
Use				
Railroad	4.6	4.9	4.0	4.0
Oil company	1.5	1.0	1.1	1.3
Gas and electric	0.2	0.2	0.2	0.1
Mine and smelter	0.1	0.5	0.2	0.2
Iron and steel	0.2	0.4	0.3	0.1
All other	0.2	0.2	0.2	0.3
Total	6.8	7.2	6.0	6.0

Source: Compiled from the "National Survey of Fuel Oil Distribution," published by the United States Bureau of Mines, except as otherwise indicated.

5. Pacific Coast Region

Million U. S. barrels

District and State	1924	1925	1926	1927	1928	1929
Southern						
California	78.3	72.7	86.6	89.8	91.7	89.6
Arizona	3.6	4.8	3.7	2.7	3.8	4.2
Nevada	..	..	0.6	0.8	1.0	1.0
Total	81.9	77.5	90.9	93.3	96.5	94.8
Northern						
Washington	8.6	7.6	7.4	8.2	10.7	11.5
Oregon	8.4	7.4	6.1	5.3	6.9	6.6
Total	17.0	15.0	13.5	13.5	17.6	18.1
Grand total	98.9	92.5	104.4	106.8	114.1	112.9
Use						
Steamship and naval	25.5	26.6	34.1	39.1	39.5	39.3
Railroad	29.3	28.8	31.0	28.3	29.1	29.6
Gas and electricity	12.9	8.4	9.3	8.2	8.5	8.7
Oil company	5.6	5.7	5.5	5.7	5.8	5.8
Heating	2.0	2.0	4.0	4.6	5.2	6.2
Mine and smelter	4.0	4.9	4.1	3.4	4.1	4.5
Iron and steel	0.9	1.3	1.2	1.6	1.5	1.7
Logging and lumber	2.4	2.9	2.7	1.7	1.8	1.7
Cement and ceramic	4.4	4.2	4.5	4.3	5.3	3.0
Food industry	2.7	2.4	3.4	3.3	3.7	3.6
All others	9.2	5.3	4.6	6.6	9.6	8.8
Total	98.9	92.5	104.4	106.8	114.1	112.9

Sources: Compiled from the "National Survey of Fuel Oil Distribution," United States Bureau of Mines and from other Bureau of Mines publications.

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